Where:

Equation XII-5 Exposure Ratio Calculation

$$\textit{Exposure Ratio (ER)} = \frac{\text{Exposure Measure to Driving Conflicts } \textbf{\textit{with}} \text{ Application Assistance}}{\text{Exposure Measure to Driving Conflicts } \textbf{\textit{without}} \text{ Application Assistance}}$$

And

Equation XII-6 Crash Prevention Ratio Calculation

$$\textit{Crash Prevention Ratio (CPR)} = \frac{\text{Crash Probability in Driving Conflict } \textbf{\textit{with}} \text{ Application Assistance}}{\text{Crash Probability in Driving Conflict } \textbf{\textit{without}} \text{ Application Assistance}}$$

The Exposure Ratio (ER) is the measure of change a safety application may have on drivers being exposed to conflict.[359] In other words, V2V safety applications may change driver behavior such that a driver can better anticipate a potential conflict and adjust such that the conflict does not occur. The change to drivers' exposure to conflicts is obtained from field observations (not simulated in SIM) during a field operational test, usually over an extended period of time. However, it may be difficult to quantify the exposure to conflicts with and without the safety application with any statistical significance due to relatively short test time periods (a driver's adaptation to a safety application usually takes longer than the 3 to 24 weeks a driver [subject] experiences the safety technology in the context of the current research). In recognition of this difficulty, a conservative estimate of the ER parameter is set to one for purposes of the present analysis, meaning that there is no difference in exposure to driving conflicts whether the V2V application is present or not.

The Crash Prevention Ratio (CPR) equation accounts for whether or not a vehicle will crash with another vehicle in a driving conflict as a result of the first vehicle's crash-avoidance action, such as braking to stop. It is estimated using a SIM computer-based simulation. The SIM's primary duty in relation to estimating the CPR is to mimic, as close to real-world as possible, the actual conditions, interactions, and performance of the driver, vehicle, and safety application of target driving conflicts corresponding to major pre-crash scenarios. This simulation uses input data from national crash databases; driver, vehicle, and V2V safety application performance data from naturalistic field operational tests (Safety Pilot Model Deployment); track tests; and related driver, vehicle, or safety application evaluation studies. Outputs of the tool consist of the number of crashes avoided and impact speed reduction that can

[359] Driving conflicts correspond to the kinematics of the target pre-crash scenarios. An exposure to a driving conflict is counted when the movements of the host vehicle and the principal other vehicle match the configuration of the driving conflict and the two vehicles are on a crash course if a crash avoidance action is not taken by either vehicle.

be translated into harm reduction, including savings in crash comprehensive costs and decreases in the number of persons injured at different levels of the MAIS.

To support the calculation of the CPR by the SIM, the simulation component needs to generate data on crashes both with and without the V2V safety applications. A 2010 report by Ford, Volvo, and UMTRI developed an approach to generating such data by using field trials to create a number of driving scenarios that are relevant to the technology/safety application in question, but may or may not lead to a crash.[360] Each scenario is evaluated without the V2V safety application, and then the same scenario can be evaluated again with the application in place. Each scenario comprises a number of "conflicts" generated using a Monte Carlo[361] approach, where a conflict is a specific driving situation (e.g., vehicle traveling at 50 mph detects a lead vehicle that is stopped 200 feet away) that would fall under the pre-crash scenario in question (e.g., lead vehicle stopped). Each conflict can be evaluated for whether a crash is avoided or does occur. If a crash is avoided, benefits are estimated based on the number of fatalities and injuries that are avoided. If a crash would occur, benefits are estimated in relation to reductions in fatalities and injuries due to possible mitigation of crash impact. A change in crash impact is measured by the change in velocity, delta-V, which can be translated into changes in fatalities and injuries. For this exercise, a similar approach was implemented into the SIM. Figure XII-2 illustrates the structure of the SIM developed to estimate V2V safety application benefits.

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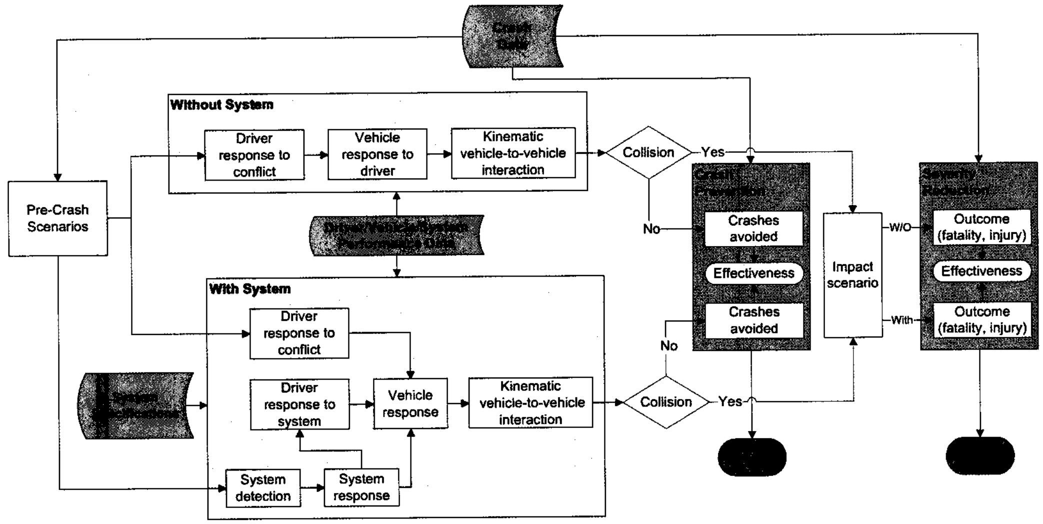
[360] Advanced Crash Avoidance Technologies (ACAT) Program – Final Report of the Volvo-Ford-UMTRI Project: Safety Impact Methodology for Lane Departure Warning – Method Development and Estimation of Benefits (Gordon et al., Oct. 2010, Report No. DOT HS 811 405). See www.nhtsa.gov/Research/Crash+Avoidance/ci.Office+of+Crash+Avoidance+Research+Technical+Publications.print (last accessed Jan. 29, 2014).

[361] A Monte Carlo simulation is a problem solving technique that builds models of possible results by substituting a range of values – a probability distribution – for any factor that has inherent uncertainty. It then calculates results over and over, each time using a different set of random values from the probability functions. Depending on the uncertainties and the ranges specified for them, a Monte Carlo simulation could involve thousands or tens of thousands of recalculations before it is complete. Monte Carlo simulation produces distributions of possible outcome values.

Figure XII-2 SIM Logic and Structure



The SIM V2V benefit estimation process used here began with the generation of pre-crash scenarios using crash statistics from the National Automotive Sampling System General Estimate System (NASS-GES) that compiles crash data from a nationally-representative sample of police-reported motor vehicle crashes of all crash types. From each scenario, specific conflicts (a combination of driver, vehicle, and scenario characteristics) were generated using probability distribution-based historical data and Safety Pilot Model Deployment data.[362] The distributions used to generate the specific conflicts included safety system performance (system activation), driver reaction time, braking level, and the vehicle speed/distance-to-collision distributions. The distributions of various characteristics support the use of a Monte Carlo approach that was used to run thousands of conflicts that were then evaluated with and without the safety application. The results from these conflict evaluations -- crashes, crashes avoided, or crashes mitigated -- were summarized, leading to system effectiveness and harm reduction ratios for the different scenario/safety application combinations. The effectiveness and harm reduction ratios for each scenario/safety application were then applied to the target population for each scenario to estimate the level of benefits that may result from each safety application. The collective benefits from the evaluated safety application provide a total estimate of benefits that can then be compared to the estimated cost for the V2V system.

[362] Each specific conflict is a single event with only the vehicles involved in the conflict included in the simulation. Unintended consequences (e.g., a crash caused by avoiding a crash) that involve other non-conflict vehicles are not captured through the simulation.

Although the SIM can generate both effectiveness and benefit estimates, only the effectiveness outcome was used in this analysis due to some refinement to the target populations that would not be considered in the SIM. The process of deriving the system effectiveness for a safety application can be briefly summarized by the following steps:

(1) Derive the initial effectiveness for various pre-crash scenarios and speed ranges (from SIM or MiniSim)
(2) Derive the overall effectiveness for each pre-crash scenario by calculating the weighted effectiveness of initial effectiveness over all speed ranges
(3) Derive the system effectiveness by calculating the weighted effectiveness of pre-crash scenario effectiveness over all pre-crash scenarios
(4) Derive the final system effectiveness by multiplying the overall effectiveness by a factor to take into account situations that were not addressed by SIM and MiniSim.

For crashworthiness, the effectiveness E_w of an application is the effect of delta-V reduction on crash severity for those crashes that cannot be avoided by the safety application, where delta-V is the recorded change in velocity experienced during a crash.[363] E_w was estimated by MAIS injury level. As stated earlier, SIM was used to generate crash impact speed distributions separately for the baseline and treatment groups. These speed distributions were used as the proxy for delta-V to estimate E_w. SIM groups the impact speeds into 16 intervals. The first interval is from 0 to less than 3 mph, noted as [0, 3), with 3 mph increment for the subsequent intervals until 46 mph. Impact speeds of 47 mph and higher were aggregated into the last interval notes as 47+ mph. SIM treats all involved vehicles with equal mass. Therefore, half of the impact speed is a substitute for delta-V of the crash. Furthermore, the mid-point of each interval was used to calculate the average delta-V for each pre-crash scenario. The sum of the products of the mid-points and their corresponding percent of distributions derives the average delta-V for that specific pre-crash scenario. Then, applying the percent of real-world crash distribution to the average delta-V derives the weighted average delta-V for a target crash type. MAIS injury probability curves were used to locate the MAIS injury probabilities at the weighted average delta-V level both for control and treatment group. The effectiveness for a MAIS level can be noted as:

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363 The vehicle resultant change in velocity, commonly referred to as simply resultant delta-V, is the primary description of crash severity in most crash databases. "Estimating Crash Severity: Can Event Data Recorders Replace Crash Reconstruction?" For additional information, see www.nhtsa.gov/DOT/NHTSA/NRD/Articles/ESV/PDF/18/Files/18ESV-000490.pdf (last accessed: January 29, 2014).

Equation XII-7 MAIS Effectiveness Calculation

$$E_w = 1 - \frac{P_t}{P_c}$$

Where, E_w = MAIS effectiveness

P_t = injury probability for the treatment group

P_c = injury probability for the control group

The following summarizes the process for deriving E_w. A detailed description of the process is contained in each of the following sections dedicated to specific applications.

(1) Derive the delta-V distribution for each of the pre-crash scenarios for baseline (i.e., without V2V) and treatment groups (with V2V).
(2) Derive an average delta-V for each scenario for the baseline and treatment groups
(3) Derive the weighed delta-V for all scenarios combined
(4) Derive injury probability curves
(5) Estimate the MAIS injury probabilities at the weighted average delta-V level using injury probability curves

In the following sections dedicated to specific safety applications, the process of deriving crash avoidance and crashworthiness effectiveness will be discussed in detail.

2. Driving Simulator Study - MiniSim

MiniSim is a driving simulator in a controlled laboratory environment, which was used for evaluating IMA and LTA applications in avoiding crashes. Drivers were recruited to drive three IMA and two LTA pre-crash scenarios. These drivers are divided into baseline (no IMA or LTA warning given) and treatment (IMA or LTA warning given) groups. The crash avoidance effectiveness (E_a) is derived from the crash rates and reaction times of these two groups.

A total of 144 drivers successfully completed the IMA study. Table XII-2 shows the experimental design and breakdown of these drivers in this study.[364] These drivers were equally divided into three groups of 48 for each of the three driving conditions listed above. Within a group, 24 drivers received an alert (treatment group) and 24 did not (baseline group). Each group is equally divided among three age groups (18 to 24, 40 to 50, and 60 or older) and by gender

[364] Summary Report for a Simulator Study of Intersection Movement Assist (IMA) and Left Turn Assist (LTA) Warning Systems (Balk, Sept. 2013, Turner-Fairbank Highway Research Center, Internal Report). See Docket No. NHTSA-2014-0022.

(i.e., male and female) as seen in Table XII-2. Each driver experienced only one of the three driving conditions.

Table XII-2 Breakdown of Drivers in IMA Study

Alert Condition	Age (Years)	Gender	Driving Condition		
			PCP-M	PCP-S Left	PCP-S Right
Baseline (No Alert)	18-24	Male	4	4	4
		Female	4	4	4
	40-50	Male	4	4	4
		Female	4	4	4
	≥ 60	Male	4	4	4
		Female	4	4	4
		Subtotal	24	24	24
Treatment (Alert)	18-24	Male	4	4	4
		Female	4	4	4
	40-50	Male	4	4	4
		Female	4	4	4
	≥ 60	Male	4	4	4
		Female	4	4	4
		Subtotal	24	24	24
		Total	48	48	48

The MiniSim design for IMA is for drivers to experience one of three driving conditions at a four-way intersection.

1. The driver approaches the intersection with a green light and another vehicle approaches from the left (PCP-M)
2. The driver approaches the intersection with a stop sign and another vehicle approaches from the left (PCP-S)
3. The driver approaches the intersection with a stop sign and another vehicle approaches from the right (PCP-S)

In all conditions, the driver is traveling at 45 mph toward the intersection and attempting to drive straight through the intersection. Just before the driver crosses into the intersection, the approaching vehicle, obscured by a stationary large truck, appears coming from the perpendicular/lateral side at a constant speed of 45 mph. If no attempt to apply the brakes was taken by the driver participating in the study, the vehicles would crash in 3.3 seconds.

The MiniSim design for LTA is for drivers to experience one of two driving conditions while making a left turn at an intersection.

1. The driver had a green light and could make the turn without stopping (LTAP/OD-M)
2. The driver had a red light initially and had to stop, and then made a left turn when the light turned green (LTAP/OD-S)

In both conditions, the driver and an approaching vehicle approach each other from opposite directions. As soon the driver started to initiate the left turn and exceeded 6 mph in speed, the approaching vehicle appeared behind the stopped truck, traveling forward at a constant speed of roughly 45 mph. If no action was taken by the driver, the two vehicles would crash in about 3.3 seconds.

A total of 96 drivers were recruited for LTA. These drivers were evenly divided into two groups of 48 each and were further evenly divided into baseline and treatment.

3. Injury probability curves

Injury probability curves predict the probabilities of MAIS injuries based on delta-V. These curves were derived from 2000-2011 CDS data. CDS is a nationally-representative sampling system of passenger vehicle crashes where at least one passenger vehicle was towed. CDS was used because it is the only nationally-representative crash database that collects both delta-V and MAIS. A logistic model is the base for developing these curves. The logistic model predicts the probability of MAIS injuries that would occur at a specific delta-V level. The dependent variable of the model is MAIS+ injury severity which is dichotomy. The value is 0 when an injury is less than a certain MAIS level and 1 if an injury is equal to or greater than that MAIS level. Delta-V is the independent variable.

The derived MAIS+ injury probability curves for a delta-V level "x" thus have the form:

Equation XII-8 MAIS+Injury Probability of Risk

$$p_{MAIS+}(x) = \frac{e^{ax+b}}{1+e^{ax+b}}$$

Where, a = 0.092845, b = -1.14421 for MAIS 1+

a = 0.13527, b = -4.51842 for MAIS 2+

a = 0.16851, b = -6.33516 for MAIS 3+

a = 0.17329, b = -7.77703 for MAIS 4+

a = 0.18588, b = -9.35528 for MAIS 5+

a = 0.19471, b = -11.70930 for fatality

The probability for certain injury level is simply the difference of two MAIS+ probabilities. In other words, $p_{MAIS1} = p_{MAIS1+} - p_{MAIS2+}$, $p_{MAIS2} = p_{MAIS2+} - p_{MAIS3+}$, and etc.

4. Crashworthiness effectiveness by MAIS

For calculating the injury reduction rates, the delta-Vs produced for the baseline and treatment were input into the MAIS+ formula. Table XII-3 presents the process. As shown, given a reduction on delta-V by 1.17 mph, IMA would mitigate MAIS 1 injuries by 6 percent, MAIS 2 injuries by 16 percent, and MAIS 4 injuries by 50 percent. Note that at the delta-V level of 8.17 and 7.00 mph levels, the probabilities of having MAIS 3+ injuries are small. Therefore, the probability estimation for MAIS 3, MAIS 4, MAIS 5, and fatality might have a greater variation for these injury levels.

Table XII-3 Probabilities of MAIS Injuries and Injury Reduction Effectiveness

Injury Severity	**Probability**		**Injury Severity**	**Probability**		**Injury Reduction Rate**
	Baseline (8.17 mph)	Treatment (7.00 mph)		Baseline (8.17 mph)	Treatment (7.00 mph)	
MAIS 1+	0.405	0.379	MAIS 1	0.373	0.352	0.06
MAIS 2+	0.032	0.027	MAIS 2	0.025	0.021	0.16
MAIS 3+	0.007	0.006	MAIS 3	0.005	0.005	0.00
MAIS 4+	0.002	0.001	MAIS 4	0.002	0.001	0.50
MAIS 5+	0.000	0.000	MAIS 5	0.000	0.000	0.00
Fatality	0.000	0.000	Fatality	0.000	0.000	0.00

Source: 2000-2011 CDS

5. Effectiveness of Intersection Movement Assist - IMA

a) IMA Crash Avoidance Effectiveness (E_a)

The effectiveness for IMA was estimated based on two major pre-crash scenarios employed in the design of the MiniSim: (1) perpendicular crossing path, with the driver stopping and then proceeding and another vehicle approaching from either the right or the left without stopping (PCP-S) and (2) perpendicular crossing path, with the driver approaching the intersection without stopping and another vehicle approaching from the left without stopping (PCP-M). The drivers' measured brake reaction time and brake deceleration level collected during the study from both the baseline and treatment MiniSim groups were then used as inputs into SIM to derive effectiveness values for various speed ranges for these pre-crash scenarios.

(1) Crash Avoidance PCP-S Crash Scenario

For the PCP-S crash scenario, MiniSim data was used to simulate crash outcomes for five different traveling speed ranges for an approaching vehicle under three separate distances between the driver (of the vehicle that stopped at the intersection and then proceeded) and the point where the driver's vehicle would make contact with the approaching vehicle. The following sections describe this process.

(a) Crash Distribution by Vehicle Speed

The agency developed a series of five bins to create a crash distribution by vehicle speed. For this evaluation, the approaching vehicle speed ranges evaluated were: [10, 25), [25, 35), [35, 45), [40, 55), and 55+ mph where the pair symbol [x, y) represents that the speed is at least x mph but less than y mph, and the plus symbol x+ represents that the speed is x mph and higher. The driver speed identified for this scenario is between 0 to 9 mph, to represent a vehicle stopped and then proceeding into the intersection. The agency developed the crash distribution shown in Table XII-4 by using these identified speed ranges as parameters in the SIM tool's Monte Carlo analysis.

Table XII-4 Percent of Crash Distribution* by Approaching Vehicle Traveling Speed (p_i)

Driver Vehicle Speed	Approaching Vehicle Travel Speed (mph)				
(mph)	[10, 25)	[25, 35)	[35, 45)	[45, 55)	55+
[0 , 10)	11.89%	9.88%	8.76%	2.95%	1.05%

*served as weight for calculating weighted effectiveness; already adjusted for unknown speed
Source: 2010-2011 GES

(b) Vehicle to Vehicle Distances Evaluated

The distance between the driver and approaching vehicle evaluated were: 3-5 meters, 4 meters, and 5-8 meters. Furthermore, the simulation was further refined by the impact location of the approaching vehicle, i.e., the left or right side of the vehicle, based on the percentages identified in Table XII-5.

Table XII-5 Percent of Impact Location*

Left Side Impact	**53.12%**
Right Side Impact	46.88%

*served as weight for calculating weighted effectiveness; already adjusted for unknown speed
Source: 2010-2011 GES

(c) IMA PCP-S Effectiveness Calculation

The IMA PCP-S scenario thus encompassed 30 initial effectiveness values, given 5 speed ranges * 2 vehicle impact locations * 3 separating distances. The weighted effectiveness for all five speed ranges and impact locations was calculated for each separating distance. This weighted effectiveness was then applied to the percentage of PCP-S crashes that occur in all IMA crashes to calculate the weighted effectiveness (E_a) using the following mathematical formula:

Equation XII-9 IMA PCP-S Crash Effectiveness Calculation

$$E_a = R \sum_{i=1}^{5} p_i * E_{a1}^{i} + (1-R) \sum_{i=1}^{5} p_i * E_{a2}^{i}$$

Where, E_a = weighted effectiveness

R = proportion of PCP-S right side impact

P_i = proportion of PCP-S in speed range i, with i=1 for [10,25) and 5 for 50+ mph

E_{a1}^{i} = effectiveness for speed range I for right side impact.

E_{a2}^{i} = effectiveness for speed range I for left side impact.

Table XII-6 provides the 30 effectiveness values calculated for using this methodology:

Table XII-6 SIM Estimated Initial Effectiveness (E_{a1}^{i} and E_{a2}^{i})

Separating	**Remote Vehicle Travel Speed (mph)**				
Distance (m)	**[10 , 25)**	**[25, 35)**	**[35, 45)**	**[45, 55)**	**55+**
Left Side					
3-5	0.71	0.66	0.64	0.56	0.45
4	0.81	0.78	0.66	0.55	0.41
5-8	0.70	0.67	0.53	0.43	0.32
Right Side					
3-5	0.70	0.70	0.64	0.59	0.48
4	0.83	0.79	0.70	0.59	0.44
5-8	0.73	0.65	0.56	0.47	0.35

(d) Summary of IMA PCP-S Effectiveness

The agency did not employ all of these initial effectiveness estimates in developing our ultimate estimate of IMA effectiveness in the PCP-S scenario. Instead, we focused on two crash distributions that best reflected our understanding of current and future system capabilities in real-world situations. Using the two distribution results in estimating a range of effectiveness that reflects the current limitation of the current prototype (but does not limit the potential impact that IMA could have on the target population it could address).

The first distribution does not include the crashes that occur between 10 to 24 mph, [10, 25), because current prototype IMA designs (like those used in the Safety Pilot model deployment) do not issue warnings unless one of the interacting vehicles is traveling at or above 25 mph. This means that the effectiveness of IMA is treated as 0 for these crashes in the first distribution. The second distribution, on the other hand, includes the [10, 25) speed interval, in order to reflect our expectation that future improvements to IMA will allow the application to operate down to 10 mph.

Using these two distributions reduced the initial set of 30 effectiveness values to a total of 3 weighted effectiveness values (as shown in Table XII-7, the agency estimates IMA would avoid 15-24 percent of PCP-S crashes), which we used for benefits estimation.

Table XII-7 Weighted IMA Effectiveness (E_a) for PCP-S Crash Scenario

	Separating Distance		
	3-5 meters	4 meters	5-8 meters
Low	0.15	0.16	0.15
High	0.23	0.24	0.24

The three weighted effectiveness values were later combined with the weighted crash avoidance effectiveness (E_a) for the PCP-M crash scenario, discussed below, to derive the final effectiveness for IMA.

(2) Crash Avoidance PCP-M Crash Scenario

For the PCP-M crash scenario, as for the PCP-S crash scenario, data generated by the MiniSim study was used as input to the SIM. The PCP-M evaluation is slightly more straightforward than for PCP-S for two reasons: first, PCP-M involves both vehicles moving, and second, PCP-M only involves the "other vehicle" approaching the driver from the left. As a result, the full range of vehicle speeds apply to both the driver and the approaching vehicle, and no accounting for vehicle impact side or vehicle to vehicle distance is evaluated.

(a) Crash Distribution by Vehicle Speeds

The same series of five bins ([10, 25), [25, 35), [35, 45), [40, 55), and 55+ mph) were used to develop a crash distribution by vehicle speed as for the PCP-S crash scenario, but since all five speed range bins are considered applicable and evaluated for both the driver and approaching vehicles, 25 crash distribution values result instead of the 5 values for PCP-S.

Table XII-8 Percent of Crash Distribution* by Approaching Vehicle Traveling Speed (p_i)

Driver Vehicle Speed	Approaching Vehicle Travel Speed (mph)				
(mph)	[10 , 25)	[25, 35)	[35, 45)	[45, 55)	55+
[10 , 25)	13.01%	11.00%	10.76%	3.50%	0.78%
[25, 35)	5.23%	3.80%	1.87%	0.85%	0.10%
[35, 45)	3.43%	1.09%	1.73%	0.58%	0.07%
[45, 55)	1.29%	0.37%	0.44%	0.65%	0.10%
55+	0.41%	0.03%	0.24%	0.07%	0.07%

*served as weight for calculating weighted effectiveness; already adjusted for unknown speed
Source: 2010-2011 GES

(b) IMA PCP-M Effectiveness Calculation

Using the same effectiveness calculation method as that for PCP-S, a total of 25 initial effectiveness values were generated by the SIM for the IMA PCP-M scenario. The reader will remember that in PCP-M, we did not consider vehicle impact side or vehicle separating distance, so the 25 initial effectiveness values reflect only the interactions of the two vehicles depending on their speed.

As discussed above for PCP-S, the initial effectiveness for the cell "driver vehicle speed [10, 25)," "approaching vehicle speed [10, 25)" was not used (i.e., treated as 0) for the effectiveness calculation given current system limitations that cause IMA not to activate below 25 mph. This cell is therefore shaded gray in Table XII-9. The wide range illustrates the uncertainty concern on the inherent computation variations including those from SIM, MiniSim, and GES sampling errors.

Table XII-9 SIM Estimated Initial Effectiveness (E_a)

Driver Vehicle Speed (mph)	Approaching Vehicle Travel Speed (mph)				
	[10 , 25)	[25, 35)	[35, 45)	[45, 55)	55+
[10 , 25)	0.47	0.51	0.55	0.57	0.60
[25, 35)	0.41	0.50	0.56	0.59	0.63
[35, 45)	0.43	0.54	0.60	0.63	0.67
[45, 55)	0.46	0.58	0.63	0.66	0.69
55+	0.49	0.62	0.66	0.67	0.69

(c) Summary of IMA PCP-M Effectiveness

Using the same methodology as the PCP-S crash scenario, the agency developed a weighted estimated effectiveness of 26 to 31 percent for IMA when a driver is involved in the PCP-M crash scenario. However, the agency again notes that the lower bound of effectiveness reflects the current prototype design of IMA, where a warning is issued when the driver is traveling above 25 mph. As mentioned above, it is anticipated that future tuning of the IMA application would allow it to operate at speeds as low as 10 mph.

(3) IMA Crash Avoidance System Effectiveness

The overall IMA system effectiveness is calculated by combining the effectiveness values of the PCP-S and PCP-M crash scenarios. This is possible because the weighted effectiveness values for these crash scenarios took into account the corresponding crash proportion for each scenario. Therefore, the overall system effectiveness is simply the sum of these two weighted effectiveness rates.

Based on the combination of the IMA PCP-S and PCP-M effectiveness values, the agency estimates IMA has the potential to help drivers avoid 41 to 55 percent of intersection crashes.[365] In other words, the agency estimates that by providing a warning that an intersection crash is about to occur, drivers will avoid 41 to 55 percent of all target IMA intersection crashes.

b) IMA Crashworthiness Effectiveness (E_w)

The crashworthiness effectiveness (E_w) for IMA was developed using crash impact speed distributions generated by the SIM. As discussed in Section XII.B.1, these crash impact distributions were used as the proxy for delta-V distributions. Additionally, injury probability curves for this analysis were derived as described in Section XII.B.3

(1) Crashworthiness PCP-S Crash Scenario

Estimates for the IMA Crashworthiness PCP-S scenario were developed based on 15 crash conditions for each impact location – left or right side (i.e., approaching vehicle traveling speeds, left and right impact locations, three separating distances). These 15 conditions were simulated using the SIM tool to produce delta-V distributions for both the baseline and treatment groups for comparison. Details for each distribution are shown in Table XIII-2 and Table XIII-3, respectively.

Table XII-10 shows the average delta-Vs that were derived by multiplying the delta-V by its corresponding distribution percentage.

Table XII-10 Derived Average Delta-V (mph) by Simulated Crash Conditions

Separating Distance (Meter)	Baseline					Treatment				
	Approaching Vehicle Speed (mph)					Approaching Vehicle Speed (mph)				
	[10, 25)	[25, 35)	[35, 45)	[45, 55)	55+	[10, 25)	[25, 35)	[35, 45)	[45, 55)	55+
Left Side Impact										
3-5	4.01	5.80	6.94	7.63	7.74	3.63	5.29	6.19	6.87	6.85
4	3.95	5.38	6.68	7.54	7.50	3.58	4.91	6.26	6.77	6.92
5-8	3.97	4.90	5.45	5.93	6.06	3.37	4.1	4.72	6.4	5.79
Right Side Impact										
3-5		5.78	6.98	7.68	7.72		5.29	6.19	6.87	6.85
4	4.12	5.50	6.60	7.93	7.57	3.58	4.91	6.26	6.77	6.92
5-8	3.77	4.27	4.95	5.44	5.18	3.37	4.1	4.72	6.4	5.79

Applying the crash distribution based on approaching vehicle traveling speed categories shown in Table XII-11 to the average delta-V provides the average delta-V for PCP-S crash scenarios.

[365] The result of adding 15 – 24 percent for PCP-S and 26 - 31 percent for PCP-M.

Table XII-11 Traveling Speed Distribution*

Approaching Vehicle Speed (mph)				
[10 , 25)	[25, 35)	[35, 45)	[45, 55)	55+
0.3091	0.2568	0.2277	0.0767	0.0273

*used as weight to calculate the delta-V level for an average PCP-S

As shown in Table XII-12, the average delta-V ranged from 4.16 to 4.95 mph for baseline crashes (without V2V) and 3.82 to 4.50 mph for treatment crashes (with V2V). This tells us that when a driver is stopped at an intersection, decides to go, and has a crash, the difference in the delta-V of that crash with or without a V2V warning is relatively small. The real benefit of V2V relates to the go/no go decision, and avoiding the crash by V2V warning the driver of the impending crash and the driver deciding not to go into the intersection.

Table XII-12 Delta-V for an Average PCP-S Crash

Separating Distance	Baseline	Treatment
3-5	4.53	4.08
4	4.95	4.50
5-8	4.16	3.82

(2) Crashworthiness PCP-M Crash Scenario

For the IMA PCP-M crash scenario, the process of deriving the delta-V for an average PCP-M crash is similar to that for PCP-S. The only difference between the two is the simulated crash conditions. There were 25 conditions for PCP-M, representing the combinations of five drivers and five approaching vehicles. Table XII-13 and Table XII-14show the parallel process to the PCP-S crash scenario for generating an average crash delta-V for a PCP-M crash.

Table XII-13 Derived Average Delta-V (mph) by Simulated Crash Conditions

Host	Baseline					Treatment				
Vehicle	Approaching Vehicle Speed (mph)					Approaching Vehicle Speed (mph)				
Speed	[10, 25)	[25, 35)	[35, 45)	[45, 55)	55+	[10, 25)	[25, 35)	[35, 45)	[45, 55)	55+
[10, 25)	7.73	7.73	7.75	7.77	7.83	5.36	5.84	6.25	6.42	6.82
[25, 35)	12.68	12.75	12.87	12.96	13.1	8.52	9.74	10.48	10.85	11.5
[35, 45)	16.21	16.45	16.67	16.86	17.21	11.62	13.51	14.51	15.07	15.94
[45, 55)	19.41	19.93	20.33	20.57	21.05	14.97	17.63	18.85	19.53	20.52
55+	21.38	22.09	22.51	22.74	23.04	18.28	21.34	22.35	22.81	23.2

Table XII-14 Traveling Speed Distribution*

Host Vehicle	Approaching Vehicle Speed (mph)				
Speed	[10 , 25)	[25, 35)	[35, 45)	[45, 55)	55+
[10, 25)	21.16%	17.89%	17.50%	5.69%	1.27%
[25, 35)	8.51%	6.18%	3.04%	1.38%	0.16%
[35, 45)	5.58%	1.77%	2.81%	0.94%	0.11%
[45, 55)	2.10%	0.60%	0.72%	1.06%	0.16%
55+	0.67%	0.05%	0.39%	0.11%	0.11%

*used as weight to calculate the delta-V level for an average PCP-S

As shown in Table XII-15, the delta-V for a baseline PCP-M is estimated to be 10.43 mph and for a treatment PCP-M is about 8.06 mph. IMA would reduce the crash severity by 2.37 mph. Thus, when both vehicles are moving before an intersection crash, and the crash still occurs, providing a V2V warning does reduce the delta-V of the crash by a noticeable level of 2.37 mph on average.

Table XII-15 Delta-V for an Average PCP-M Crash

	Baseline	Treatment
Delta-V (mph)	10.43	8.06

c) IMA Crashworthiness System Effectiveness

For IMA crashes as a whole, i.e., PCP-S and PCP-M combined, the average delta-V for IMA crashes is the weighted average of individual delta-Vs for PCP-S and PCP-M. Of the IMA crashes, PCP-S comprised about 38.97 percent of the crashes and PCP-M comprised 61.03 percent of the crashes. Applying these factors to the corresponding individual delta-V shown in Table XII-12 and Table XII-15 derives the average delta-V for IMA crashes. For the baseline IMA crashes, the average delta-V is about 8.17 mph and 7.00 mph for a treatment IMA crash. IMA would reduce the severity of IMA crashes by an average of 1.17 mph delta-V.

The average delta-V of 8.17 mph and 7.00 mph for the baseline and treatment IMA crashes were then input into the injury probability curves to assess the probability that a person would receive a certain level of MAIS injuries. The resulting probabilities for the baseline and treatment groups were used to estimate the reduction rate (i.e., crashworthiness effectiveness) for each of MAIS level.

6. Effectiveness of Left Turn Assist - LTA

a) LTA Effectiveness Analysis Overview

LTA is designed to assist the driver of the left turning vehicle in deciding whether to proceed with a left-turn maneuver at an intersection. LTA is not expected to influence the movement of an approaching vehicle. As such, LTA is considered to have no impact on mitigating the severity of the LTA crashes that cannot be avoided and no crashworthiness effectiveness is estimated for LTA in this analysis.

The effectiveness of Left Turn Assist, E_a for LTA, is based on the MiniSim results from 96 volunteer drivers. For each condition, half of drivers experienced an alert (the treatment group) and half did not (the control group). Therefore, for each group, only one set of effectiveness was used for each of the LTA pre-crash conditions.

b) LTA Crash Scenarios

LTA target crashes were categorized into two pre-crash scenarios that correspond to the crash design of MiniSim:

- Left Turn Across Path, Opposite Direction: an approaching vehicle continues to cross straight while the driver continues to move and turns left across the path of the other. This is scenario is abbreviated as LTAP/OD – M for moving.
- Left Turn Across Path, Opposite Direction: an approaching vehicle continues to cross straight while the driver first stops and later turns left across the path of the other. This is scenario is abbreviated as LTAP/OD – S for stopped.

(1) LTAP/OD – M MiniSim Test Scenario

In the LTAP/OD – M simulation, the driver approaches an intersection and is asked to turn left through a green light. There is a stopped truck waiting to turn left, blocking the vision of the subject driver of the next lane over. As the driver enters the intersection, a vehicle approaches the intersection along the side of the stopped truck.

(2) LTAP/OD – S MiniSim Test Scenario

In the LTAP/OD – S condition, the driver approaches the same intersection but the light is red. The driver must stop and then when the light turns green and the driver initiates the turn and reaches 6 mph, the approaching vehicle appears and approaches the intersection with a constant speed of 45 mph.

c) LTA Effectiveness Analysis Assumptions

The effectiveness analysis for LTA crashes identifies some scenarios or conditions where LTA may not be effective or operate properly. In these conditions, such as where the approaching vehicle speed is less than 10 mph, LTA effectiveness is treated as 0. In this very low speed condition, there is the possibility of many false alarms being issued and manufacturers may very well choose not to implement LTA to be active in this condition.

d) LTA Effectiveness Analysis Results

Based on the 96 volunteer driver results, LTA would prevent 75 percent of LTAP-M crashes and 33 percent of LTAP-S crashes. These effectiveness rates then were weighted by their corresponding crash proportion to derive the overall E_a. As shown in Table XI-16, LTA would prevent 48 - 62 percent of LTA crashes. However, according to the current design of LTA, LTA would be activated only when the left turn signal is initiated. Otherwise, you would constantly be given a warning every time a vehicle approached from the other direction.

Based on an SAE study by Richard Ponziani, about 75 percent of drivers would use the turn single when making left turns. Therefore, the derived effectiveness at lower bound was further discounted by 25 percent to 36 percent (48*0.75 = 0.36). This serves as the lower bound of final LTA effectiveness. The agency believes that, if drivers realized the benefit of LTA over time, drivers would be more likely to use the turn single when turning.

Table XII-16 Effectiveness for LTAP-M and LTAP-S

	LTAP-M	**LTAP-S**
Effectiveness	75%	33%
Crash Proportion*		
Low	0.5570	0.1942
High	0.7140	0.2434

*sum does not add up to100% because some LTA crashes do not belong to either of these conditions

Therefore, the 62 percent is treated as the high bound of the effectiveness. LTA would avoid 36 to 62 percent of the LTA crashes. The wide range addresses the uncertainty for the estimate.

Table XII-17 System Effectiveness

	Low	**High**
Initial	48%	62%
Final**	36%	62%

**Adjusted for turn signal use but only for lower bound

7. Summary of IMA and LTA effectiveness

Table XII-18 summarizes the crash avoidance and crashworthiness effectiveness for IMA and LTA that were derived from the previous sections. As shown, IMA would prevent 41-55 percent of IMA crashes and LTA would prevent 36-62 percent of LTA crashes.

Table XII-18 System Effectiveness of IMA and LTA

Crash Avoidance (E_a)

	IMA	**LTA**
Low	41%	36%
High	55%	62%

Crashworthiness (Ew)

Injury Severity	IMA	LTA
MAIS 1	6%	Not Applicable (NA)
MAIS 2	16%	NA
MAIS 3	0%	NA
MAIS 4	50%	NA
MAIS 5	0%	NA
Fatality	0%	NA

C. Fleet communication rate (C_i)

The probability that two vehicles can communicate with each other depends on the number of V2V-equipped vehicles (OBE, ASD, and VAD) and the total number of on-road operational passenger vehicles (i.e., the registered vehicles). The number of V2V-equipped vehicles varies with the technology implementation scenarios. The number of on-road operational passenger vehicles was derived from the estimates of new vehicle sales and the scrappage rate of vehicles. Readers can consult Appendix A for the technology plan and the detailed process of estimating the on-road light vehicle fleet.

The communication rate C_i for two V2V-equipped vehicles encountered at the ith year can be noted as:

Equation XII-10 Communication Rate Calculation

$$\frac{N_i}{O_i} * \frac{N_i}{O_i}, \text{ i.e., } C_i = \left(\frac{N_i}{O_i}\right)^2,$$

Where N_i represents the total number of vehicles that had equipped either OBE or ASD, O_i represents the total on-road light vehicle fleet for year i. Note that any two vehicles that can communicate with each other should be treated as selection without replacement. In other words, C_i should be $\frac{N_i}{O_i} * \frac{N_i\text{-}1}{O_i\text{-}1}$. However, N_i and O_i are large. The two values, $\frac{N_i}{O_i} * \frac{N_i\text{-}1}{O_i\text{-}1}$ and $\left(\frac{N_i}{O_i}\right)^2$, are almost identical. For simplicity, the square form is used for calculating the communication rate C_i. Also note that the difference in C_i among geographic areas and driving patterns by different age of vehicles were not examined in the analysis since these factors are not expected to impact the overall communication rate at the national level.

Table XIII-5 shows the communication rates from 2020 to 2059 for the three technology implementation scenarios. As shown, the communication rates for Scenarios 1 and 2 accelerate faster as time passes. It will take 12 years to reach the 50 percent communication rate for Scenario 1, but only five years later (i.e., at year 17), the communication rate would reach 75 percent. Scenario 2 would reach the 50 and 75 communication rates three years later than Scenario 1. As expected, the communication rate for Scenario 3 is low. The disparity among these three scenarios demonstrates the impact of the implementation pace on communication rate, and thus on benefits. Note that the V2V benefit can be realized only when one of the involved vehicles is equipped with safety applications. The communication rate for Scenario 2 represents the communication rate between two vehicles where at least one of them had safety applications.

The communication rates were further segregated by vehicle type (i.e., PCs and LTVs). Communication rate for PCs is the probability for PCs communicating among PCs plus the probability that PCs are communicating with LTVs. Similarly, communication rate for LTVs is the probability of LTVs communicating among LTVs plus the probability of LTVs communicating with PCs. The communication rates for PCs and LTVs are later used to divide the overall annual benefits into PC and LTV portions of benefits for calculating benefits by vehicle model year (MY). Table XIII-6 shows the communication rates by vehicle types.

D. Projected benefits of V2V technology

This section provides the undiscounted preliminary annual maximum benefits, annual benefit by calendar years. Benefits can be derived by multiplying these three factors: target population, the effectiveness, and the communication rates as mathematically noted in using Equation XII-1. The maximum represent the benefits when all on-road passenger vehicles were equipped with DSRC and IMA and LTA safety applications. The maximum benefits would be achievable under Scenarios 1 and 2 but not Scenario 3. The maximum benefits are discussed first and followed by three parallel sections, each for a scenario, describing the annual estimated benefits per calendar year.

1. Maximum annual estimated benefits

Table XII-19 shows the non-discounted annual preliminary maximum estimated benefits based on all passenger vehicles (PVs) being equipped with only IMA and LTA and the communication rate reaches 100 percent among PVs. The maximum estimated benefit would be identical for the first two technology implementation scenarios. The difference among the two scenarios is when (i.e., how fast) the maximum estimated benefit can be achieved. The third scenario would not achieve this maximum benefit level since the communication rate for this scenario would not reach 100 percent. As shown, IMA and LTA combined would prevent 412,512 to 592,230 crashes, save 777 to 1,083 lives, reduce 191,202 to 270,011 MAIS 1-5 injuries, and eliminate 511,118 to 728,173 property-damage-only vehicles (PDOVs).

Of the above estimated benefits, IMA would prevent 310,451 to 416,458 crashes, save 671 to 900 lives, reduce 136,959 to 176,593 MAIS 1-5 injuries, and eliminate 399,431 to 535,823 PDOVs. LTA would avoid 102,061 to 175,772 crashes, save 106 to 183 lives, reduce 54,243 to 93,418 MAIS 1-5 injuries, and eliminate 111,687 to 192,350 PDOVs.

Table XII-19 Non-Discounted Annual Preliminary Maximum Estimated Benefit Summary

All Passenger Vehicles Equipped With V2V Technology

	IMA		LTA		Combined	
	Low	High	Low	High	Low	High
Crashes	310,451	416,458	102,061	175,772	412,512	592,230
Fatalities	671	900	106	183	777	1,083
MAIS 1-5 Injuries	136,959	176,593	54,243	93,418	191,202	270,011
PDOV**	399,431	535,823	111,687	192,350	511,118	728,173

*Based on only IMA and LTA safety applications

**Property Damage Only Vehicles

2. Annual Estimated Benefits by Calendar Year

a) Scenario 1

Table XIII-7 shows the undiscounted preliminary estimated benefits by calendar year, separately for the three technology implementation scenarios. As expected, the potential benefits realized by IMA and LTA accrue more slowly for the first few years due to the slow build-up of communication rate among PVs. As shown, at Year 2020, the first year of technology implementation, IMA and LTA could potentially prevent 248-355 crashes and potentially avoid 412,000 to 592,000 crashes annually after 36 years of implementation.

b) Scenario 2

Table XIII-8 shows the undiscounted preliminary benefit estimates by calendar year for Scenario 2. As shown, at Year 2020, the first year of technology implementation, this scenario could potentially prevent 124 to 178 crashes, about 50 percent of the level that can be achieved by Scenario 1. After 10 years of implementation, in Year 2030, this scenario could potentially prevent 121,526 to 174,471 crashes, about 80 percent of the level in Scenario 1. Eventually, Scenario 2 would reach a similar level of annual benefits as Scenario 1, after 38 years of implementation in Year 2058 and potentially prevent 412,000 to 591,000 crashes annually.

c) Scenario 3

Table XIII-9 shows the undiscounted preliminary benefit estimates by calendar year for this scenario. As shown, Scenario 3 appears that it would have negligible impact on safety for the first year of implementation of the IMA and LTA safety applications. Starting in the second year, the benefits for this scenario are estimated to gradually increase. After 38 years of implementation, in Year 2058, a potential of 25,782 to 37,014 crashes could be prevented, 49 to 68 lives could be saved, and 11,950 to 16,876 MAIS 1-5 injuries would be reduced. The preliminary benefits from Scenario 3 are about six percent of the maximum benefits that could be achieved by Scenarios 1 and 2. The disparity in preliminary benefits demonstrates that in order to realize the full potential of V2V technology, achieving full implementation over time is critical.

XIII. Appendix A: Tables

Table XIII-1 RSE Data Cost per Vehicle

	Scenario 1	Scenario 2	Scenario 3
Year 4	$11.63	$10.74	$8.58
Year 5	$5.37	$4.93	$3.37
Year 6	$5.98	$5.45	$3.89
Year 7	$6.60	$5.98	$4.44
Year 8	$7.21	$6.49	$6.49
Year 9	$7.83	$6.98	$6.98
Year 10	$8.45	$7.49	$7.49
Year 11	$9.06	$7.96	$7.96
Year 12	$9.68	$8.43	$8.43
Year 13	$10.29	$8.90	$8.90
Year 14	$10.91	$9.38	$9.38
Year 15	$11.52	$9.81	$9.81
Year 16	$10.53	$8.88	$8.88
Year 17	$9.24	$7.72	$7.72
Year 18	$9.24	$7.65	$7.65
Year 19	$15.78	$12.97	$12.97
Year 20	$11.11	$9.04	$9.04
Year 21	$11.11	$8.94	$8.94
Year 22	$11.11	$8.81	$8.81
Year 23	$11.11	$9.11	$9.11
Year 24	$11.11	$9.06	$9.06
Year 25	$11.11	$9.01	$9.01
Year 26	$11.11	$8.96	$8.96
Year 27	$11.11	$8.91	$8.91
Year 28	$11.11	$8.86	$8.86
Year 29	$11.11	$8.81	$8.81
Year 30	$11.11	$8.77	$8.77
Year 31	$10.17	$7.99	$7.98
Year 32	$9.24	$7.25	$7.25
Year 33	$9.24	$7.25	$7.25
Year 34	$15.78	$12.39	$12.39
Year 35	$11.11	$8.72	$8.72
Year 36	$11.11	$8.72	$8.72
Year 37	$11.11	$8.72	$8.72
Year 38	$11.11	$8.72	$8.72
Year 39	$11.11	$8.72	$8.72
Year 40	$11.11	$8.72	$8.72

Table XIII-2 PCP-S Scenario - Delta-V* Distribution by Approaching Vehicle Traveling Speed Baseline (Without V2V)

	Left Side Impact					Right Side Impact				
Delta-V	Approaching Vehicle Travel Speed (mph)					Approaching Vehicle Travel Speed (mph)				
(mph)	[10, 25)	[25, 35)	[35, 45)	[45, 55)	55+	[10, 25)	[25, 35)	[35, 45)	[45, 55)	55+
Separating Distance: 3-5 Meters										
0.75	8.0%	6.6%	6.1%	6.5%	6.6%		6.6%	6.1%	6.5%	6.6%
2.25	25.2%	21.2%	20.4%	21.7%	19.7%		21.1%	20.5%	21.8%	19.6%
3.75	43.4%	42.5%	43.0%	40.6%	41.7%		42.3%	43.2%	40.8%	41.6%
5.25	9.1%	6.6%	7.5%	9.1%	9.7%		6.6%	7.6%	9.1%	9.7%
6.75	3.8%	0.0%	0.0%	0.0%	0.0%		0.0%	0.0%	0.0%	0.0%
8.25	3.6%	0.0%	0.0%	0.0%	0.0%		0.0%	0.0%	0.0%	0.0%
9.75	3.6%	0.0%	0.0%	0.0%	0.0%		0.0%	0.0%	0.0%	0.0%
11.25	3.1%	0.0%	0.0%	0.0%	0.0%		0.0%	0.0%	0.0%	0.0%
12.75	0.2%	7.3%	0.0%	0.0%	0.0%		7.2%	0.0%	0.0%	0.0%
14.25	0.0%	7.1%	0.0%	0.0%	0.0%		7.0%	0.0%	0.0%	0.0%
15.75	0.0%	6.4%	0.0%	0.0%	0.0%		6.4%	0.0%	0.0%	0.0%
17.25	0.0%	2.3%	5.4%	0.0%	0.0%		2.3%	5.4%	0.0%	0.0%
18.75	0.0%	0.0%	7.1%	0.0%	0.0%		0.0%	7.1%	0.0%	0.0%
20.25	0.0%	0.0%	7.2%	0.0%	0.0%		0.0%	7.3%	0.0%	0.0%
21.75	0.0%	0.0%	3.2%	4.2%	0.0%		0.0%	3.3%	4.2%	0.0%
23.25	0.0%	0.0%	0.0%	18.0%	22.3%		0.0%	0.0%	18.1%	22.2%
Separating Distance: 4 Meters										
0.75	8.0%	5.7%	5.1%	4.3%	4.2%	8.3%	5.8%	5.1%	4.6%	4.3%
2.25	24.2%	21.7%	21.0%	20.5%	19.3%	25.3%	22.2%	20.7%	21.6%	19.4%
3.75	46.1%	46.8%	45.5%	44.2%	45.5%	48.2%	47.8%	45.0%	46.5%	45.9%
5.25	8.5%	6.7%	7.1%	9.7%	10.4%	8.9%	6.9%	7.1%	10.2%	10.5%
6.75	3.8%	0.0%	0.0%	0.0%	0.0%	4.0%	0.0%	0.0%	0.0%	0.0%
8.25	3.3%	0.0%	0.0%	0.0%	0.0%	3.4%	0.0%	0.0%	0.0%	0.0%
9.75	2.8%	0.0%	0.0%	0.0%	0.0%	2.9%	0.0%	0.0%	0.0%	0.0%
11.25	3.0%	0.0%	0.0%	0.0%	0.0%	3.1%	0.0%	0.0%	0.0%	0.0%
12.75	0.1%	6.3%	0.0%	0.0%	0.0%	0.1%	6.4%	0.0%	0.0%	0.0%
14.25	0.0%	5.9%	0.0%	0.0%	0.0%	0.0%	6.1%	0.0%	0.0%	0.0%
15.75	0.0%	5.4%	0.0%	0.0%	0.0%	0.0%	5.6%	0.0%	0.0%	0.0%
17.25	0.0%	1.4%	5.3%	0.0%	0.0%	0.0%	1.4%	5.3%	0.0%	0.0%
18.75	0.0%	0.0%	6.2%	0.0%	0.0%	0.0%	0.0%	6.1%	0.0%	0.0%
20.25	0.0%	0.0%	6.9%	0.0%	0.0%	0.0%	0.0%	6.8%	0.0%	0.0%
21.75	0.0%	0.0%	2.8%	3.8%	0.0%	0.0%	0.0%	2.8%	3.9%	0.0%
23.25	0.0%	0.0%	0.0%	17.5%	20.6%	0.0%	0.0%	0.0%	18.4%	20.8%
Separating Distance: 5-8 Meters										
0.75	4.9%	2.4%	1.0%	0.7%	0.0%	4.7%	2.1%	0.9%	0.6%	0.0%
2.25	23.5%	15.8%	9.4%	9.5%	10.3%	22.3%	13.8%	8.6%	8.7%	8.8%
3.75	33.6%	30.4%	31.4%	33.3%	28.4%	31.8%	26.5%	28.5%	30.5%	24.3%
5.25	31.7%	38.9%	46.7%	42.7%	45.5%	30.1%	33.9%	42.4%	39.2%	38.8%
6.75	4.2%	6.0%	4.6%	6.0%	7.9%	4.0%	5.2%	4.1%	5.5%	6.8%
8.25	0.7%	0.0%	0.0%	0.0%	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%
9.75	0.7%	0.0%	0.0%	0.0%	0.0%	0.6%	0.0%	0.0%	0.0%	0.0%
11.25	0.7%	0.0%	0.0%	0.0%	0.0%	0.6%	0.0%	0.0%	0.0%	0.0%
12.75	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%
14.25	0.0%	2.2%	0.0%	0.0%	0.0%	0.0%	1.9%	0.0%	0.0%	0.0%

Delta-V (mph)	Left Side Impact: Approaching Vehicle Travel Speed (mph)					Right Side Impact: Approaching Vehicle Travel Speed (mph)				
	[10, 25)	[25, 35)	[35, 45)	[45, 55)	55+	[10, 25)	[25, 35)	[35, 45)	[45, 55)	55+
15.75	0.0%	2.3%	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%	0.0%
17.25	0.0%	0.4%	2.1%	0.0%	0.0%	0.0%	0.4%	1.9%	0.0%	0.0%
18.75	0.0%	0.0%	2.9%	0.0%	0.0%	0.0%	0.0%	2.7%	0.0%	0.0%
20.25	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	0.7%	0.0%	0.0%
21.75	0.0%	0.0%	1.0%	0.7%	0.0%	0.0%	0.0%	0.9%	0.6%	0.0%
23.25	0.0%	0.0%	0.0%	7.2%	7.9%	0.0%	0.0%	0.0%	6.6%	6.8%

*equivalent to half of the crash impact speed

Source: SIM simulation output

Table XIII-3 PCP-S Scenario - Delta-V* Distribution by Approaching Vehicle Traveling Speed Treatment (With V2V)

	Left Side Impact					Right Side Impact				
Delta-V	Approaching Vehicle Speed (mph)					Approaching Vehicle Speed (mph)				
(mph)	[10, 25)	[25, 35)	[35, 45)	[45, 55)	55+	[10, 25)	[25, 35)	[35, 45)	[45, 55)	55+
Separating Distance: 3-5 Meters										
0.75	16.7%	15.8%	16.5%	15.8%	16.3%		15.8%	16.5%	15.8%	16.3%
2.25	31.4%	30.6%	29.6%	31.5%	30.9%		30.6%	29.6%	31.5%	30.9%
3.75	29.7%	26.4%	27.5%	28.2%	27.2%		26.4%	27.5%	28.2%	27.2%
5.25	7.8%	4.5%	5.0%	3.6%	5.1%		4.5%	5.0%	3.6%	5.1%
6.75	3.9%	0.0%	0.0%	0.0%	0.0%		0.0%	0.0%	0.0%	0.0%
8.25	3.9%	0.0%	0.0%	0.0%	0.0%		0.0%	0.0%	0.0%	0.0%
9.75	3.8%	0.0%	0.0%	0.0%	0.0%		0.0%	0.0%	0.0%	0.0%
11.25	2.7%	0.0%	0.0%	0.0%	0.0%		0.0%	0.0%	0.0%	0.0%
12.75	0.2%	7.9%	0.0%	0.0%	0.0%		7.9%	0.0%	0.0%	0.0%
14.25	0.0%	7.3%	0.0%	0.0%	0.0%		7.3%	0.0%	0.0%	0.0%
15.75	0.0%	5.6%	0.0%	0.0%	0.0%		5.6%	0.0%	0.0%	0.0%
17.25	0.0%	1.9%	5.3%	0.0%	0.0%		1.9%	5.3%	0.0%	0.0%
18.75	0.0%	0.0%	6.5%	0.0%	0.0%		0.0%	6.5%	0.0%	0.0%
20.25	0.0%	0.0%	7.2%	0.0%	0.0%		0.0%	7.2%	0.0%	0.0%
21.75	0.0%	0.0%	2.4%	4.5%	0.0%		0.0%	2.4%	4.5%	0.0%
23.25	0.0%	0.0%	0.0%	16.4%	20.4%		0.0%	0.0%	16.4%	20.4%
Separating Distance: 4 Meters										
0.75	16.2%	16.1%	12.5%	13.3%	13.5%	16.2%	16.1%	12.5%	13.3%	13.5%
2.25	32.3%	31.2%	31.2%	32.5%	31.2%	32.3%	31.2%	31.2%	32.5%	31.2%
3.75	30.2%	28.0%	29.1%	28.5%	28.4%	30.2%	28.0%	29.1%	28.5%	28.4%
5.25	8.1%	5.7%	6.2%	5.8%	6.6%	8.1%	5.7%	6.2%	5.8%	6.6%
6.75	3.6%	0.0%	0.0%	0.0%	0.0%	3.6%	0.0%	0.0%	0.0%	0.0%
8.25	3.5%	0.0%	0.0%	0.0%	0.0%	3.5%	0.0%	0.0%	0.0%	0.0%
9.75	3.1%	0.0%	0.0%	0.0%	0.0%	3.1%	0.0%	0.0%	0.0%	0.0%
11.25	3.0%	0.0%	0.0%	0.0%	0.0%	3.0%	0.0%	0.0%	0.0%	0.0%
12.75	0.1%	6.9%	0.0%	0.0%	0.0%	0.1%	6.9%	0.0%	0.0%	0.0%
14.25	0.0%	5.6%	0.0%	0.0%	0.0%	0.0%	5.6%	0.0%	0.0%	0.0%
15.75	0.0%	5.2%	0.0%	0.0%	0.0%	0.0%	5.2%	0.0%	0.0%	0.0%
17.25	0.0%	1.5%	5.3%	0.0%	0.0%	0.0%	1.5%	5.3%	0.0%	0.0%
18.75	0.0%	0.0%	6.5%	0.0%	0.0%	0.0%	0.0%	6.5%	0.0%	0.0%
20.25	0.0%	0.0%	6.4%	0.0%	0.0%	0.0%	0.0%	6.4%	0.0%	0.0%
21.75	0.0%	0.0%	2.9%	4.1%	0.0%	0.0%	0.0%	2.9%	4.1%	0.0%
23.25	0.0%	0.0%	0.0%	15.8%	20.2%	0.0%	0.0%	0.0%	15.8%	20.2%
Separating Distance: 5-8 Meters										
0.75	9.5%	7.4%	4.9%	0.7%	2.1%	9.5%	7.4%	4.9%	0.7%	2.1%
2.25	35.8%	30.2%	31.5%	21.0%	22.7%	35.8%	30.2%	31.5%	21.0%	22.7%
3.75	34.9%	37.6%	31.0%	37.0%	39.2%	34.9%	37.6%	31.0%	37.0%	39.2%
5.25	14.8%	16.3%	23.4%	26.1%	22.7%	14.8%	16.3%	23.4%	26.1%	22.7%
6.75	2.2%	1.6%	1.1%	2.2%	3.1%	2.2%	1.6%	1.1%	2.2%	3.1%
8.25	1.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%
9.75	1.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%
11.25	0.7%	0.0%	0.0%	0.0%	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%
12.75	0.0%	2.3%	0.0%	0.0%	0.0%	0.0%	2.3%	0.0%	0.0%	0.0%
14.25	0.0%	2.3%	0.0%	0.0%	0.0%	0.0%	2.3%	0.0%	0.0%	0.0%

	Left Side Impact					Right Side Impact				
Delta-V	**Approaching Vehicle Speed (mph)**					**Approaching Vehicle Speed (mph)**				
(mph)	**[10, 25)**	**[25, 35)**	**[35, 45)**	**[45, 55)**	**55+**	**[10, 25)**	**[25, 35)**	**[35, 45)**	**[45, 55)**	**55+**
15.75	0.0%	1.9%	0.0%	0.0%	0.0%	0.0%	1.9%	0.0%	0.0%	0.0%
17.25	0.0%	0.4%	3.8%	0.0%	0.0%	0.0%	0.4%	3.8%	0.0%	0.0%
18.75	0.0%	0.0%	2.2%	0.0%	0.0%	0.0%	0.0%	2.2%	0.0%	0.0%
20.25	0.0%	0.0%	1.6%	0.0%	0.0%	0.0%	0.0%	1.6%	0.0%	0.0%
21.75	0.0%	0.0%	0.5%	0.7%	0.0%	0.0%	0.0%	0.5%	0.7%	0.0%
23.25	0.0%	0.0%	0.0%	12.3%	10.3%	0.0%	0.0%	0.0%	12.3%	10.3%

*equivalent to half of the crash impact speed
Source: SIM simulation output

Table XIII-4 PCP-M Scenario - Delta-V* Distribution by Approaching Vehicle Speed

	Baseline					**Treatment**				
Delta-V	**Approaching Vehicle Speed (mph)**					**Approaching Vehicle Speed (mph)**				
(mph)	**[10, 25)**	**[25, 35)**	**[35, 45)**	**[45, 55)**	**55+**	**[10, 25)**	**[25, 35)**	**[35, 45)**	**[45, 55)**	**55+**
Driver Vehicle Speed **[10, 25)**										
0.75	0.5%	0.5%	0.2%	0.1%	0.0%	4.4%	1.6%	0.7%	0.4%	0.0%
2.25	1.8%	1.8%	1.6%	1.4%	0.9%	13.6%	8.8%	5.6%	4.5%	2.5%
3.75	5.4%	5.4%	5.6%	5.4%	5.0%	21.2%	20.2%	16.5%	15.1%	12.2%
5.25	18.2%	18.0%	18.4%	18.7%	18.7%	22.4%	24.3%	24.1%	23.6%	21.3%
6.75	20.5%	20.6%	20.9%	20.9%	21.1%	18.1%	20.9%	24.0%	25.0%	25.2%
8.25	20.3%	20.6%	20.1%	20.1%	20.4%	12.3%	14.4%	17.4%	19.0%	22.8%
9.75	18.8%	18.8%	18.5%	18.7%	19.1%	6.4%	7.6%	9.1%	9.6%	12.7%
11.25	14.1%	14.0%	14.1%	14.1%	14.2%	1.7%	2.2%	2.5%	2.8%	3.2%
12.75	0.5%	0.5%	0.5%	0.5%	0.5%	0.0%	0.0%	0.1%	0.1%	0.1%
14.25	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
15.75	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
17.25	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
18.75	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
20.25	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
21.75	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
23.25	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Driver Vehicle Speed **[25, 35)**										
0.75	0.1%	0.0%	0.0%	0.0%	0.0%	0.6%	0.0%	0.0%	0.0%	0.0%
2.25	0.2%	0.0%	0.0%	0.0%	0.0%	2.8%	0.1%	0.0%	0.0%	0.0%
3.75	0.6%	0.2%	0.0%	0.0%	0.0%	6.5%	0.9%	0.1%	0.0%	0.0%
5.25	1.2%	1.0%	0.5%	0.1%	0.0%	11.7%	4.8%	1.4%	0.5%	0.0%
6.75	2.3%	2.3%	1.8%	1.2%	0.3%	16.0%	12.8%	6.9%	4.2%	0.9%
8.25	4.4%	4.7%	4.4%	4.1%	2.9%	17.7%	20.6%	17.1%	14.0%	7.7%
9.75	8.4%	8.4%	8.4%	8.4%	8.0%	16.9%	23.2%	25.5%	25.1%	21.7%
11.25	15.2%	15.4%	15.7%	15.8%	16.5%	14.2%	19.1%	24.1%	27.8%	30.3%
12.75	26.7%	26.6%	27.2%	27.6%	28.3%	9.1%	12.0%	15.8%	18.1%	24.9%
14.25	22.8%	23.1%	23.3%	23.9%	24.9%	3.6%	5.4%	7.6%	8.5%	11.9%
15.75	15.4%	15.7%	16.0%	16.2%	16.3%	0.8%	1.2%	1.4%	1.8%	2.6%
17.25	2.6%	2.5%	2.7%	2.7%	2.7%	0.0%	0.0%	0.0%	0.0%	0.0%
18.75	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
20.25	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
21.75	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
23.25	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Driver Vehicle Speed **[35, 45)**										
0.75	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
2.25	0.1%	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%
3.75	0.2%	0.0%	0.0%	0.0%	0.0%	1.6%	0.0%	0.0%	0.0%	0.0%
5.25	0.5%	0.0%	0.0%	0.0%	0.0%	3.8%	0.1%	0.0%	0.0%	0.0%
6.75	1.1%	0.2%	0.0%	0.0%	0.0%	6.8%	0.8%	0.0%	0.0%	0.0%
8.25	1.9%	1.1%	0.3%	0.0%	0.0%	10.9%	3.2%	0.8%	0.1%	0.0%
9.75	2.8%	2.7%	1.4%	0.7%	0.0%	14.5%	9.1%	3.5%	1.3%	0.0%
11.25	4.8%	4.6%	4.0%	3.1%	1.0%	16.0%	16.0%	10.5%	6.6%	2.2%
12.75	7.1%	7.6%	7.6%	7.0%	4.7%	14.2%	21.3%	19.1%	16.4%	9.1%
14.25	11.1%	11.4%	11.9%	11.9%	11.2%	13.0%	21.0%	24.7%	24.2%	21.4%
15.75	16.2%	17.2%	17.8%	18.1%	19.4%	9.6%	15.2%	20.7%	25.8%	27.4%

Delta-V (mph)	Baseline					Treatment				
	Approaching Vehicle Speed (mph)					Approaching Vehicle Speed (mph)				
	[10, 25)	[25, 35)	[35, 45)	[45, 55)	55+	[10, 25)	[25, 35)	[35, 45)	[45, 55)	55+
17.25	22.0%	22.2%	23.3%	24.1%	25.7%	5.6%	8.7%	12.9%	16.4%	24.0%
18.75	18.5%	18.7%	19.3%	20.1%	21.4%	2.6%	3.9%	6.1%	7.3%	12.6%
20.25	11.4%	11.7%	11.7%	12.2%	13.3%	0.8%	1.0%	1.7%	1.9%	3.2%
21.75	2.4%	2.5%	2.6%	2.8%	3.2%	0.0%	0.0%	0.0%	0.0%	0.0%
23.25	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Driver Vehicle Speed [45, 55)										
0.75	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.25	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.75	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%
5.25	0.1%	0.0%	0.0%	0.0%	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%
6.75	0.4%	0.0%	0.0%	0.0%	0.0%	1.9%	0.0%	0.0%	0.0%	0.0%
8.25	0.6%	0.0%	0.0%	0.0%	0.0%	4.1%	0.0%	0.0%	0.0%	0.0%
9.75	1.3%	0.2%	0.0%	0.0%	0.0%	6.6%	0.2%	0.0%	0.0%	0.0%
11.25	2.1%	0.8%	0.1%	0.0%	0.0%	9.8%	1.8%	0.1%	0.0%	0.0%
12.75	3.3%	2.3%	0.8%	0.2%	0.0%	12.7%	5.1%	1.3%	0.4%	0.0%
14.25	4.8%	4.6%	2.8%	1.5%	0.1%	14.6%	10.9%	5.1%	2.4%	0.2%
15.75	7.0%	7.0%	6.2%	4.8%	1.9%	14.0%	17.8%	10.9%	6.8%	2.6%
17.25	9.5%	9.9%	9.7%	9.6%	6.8%	11.9%	20.0%	18.8%	15.6%	8.2%
18.75	12.9%	13.6%	14.4%	14.9%	14.3%	9.9%	17.7%	23.5%	22.4%	18.4%
20.25	16.4%	17.2%	18.7%	19.6%	21.4%	6.9%	13.2%	19.5%	25.2%	27.5%
21.75	18.6%	19.4%	20.9%	22.0%	24.2%	4.0%	8.0%	12.4%	16.4%	24.6%
23.25	23.0%	25.0%	26.4%	27.4%	31.4%	2.8%	5.2%	8.2%	10.7%	18.5%
Driver Vehicle Traveling Speed 55+										
0.75	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.25	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.75	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.25	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
6.75	0.1%	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%
8.25	0.2%	0.0%	0.0%	0.0%	0.0%	0.9%	0.0%	0.0%	0.0%	0.0%
9.75	0.5%	0.0%	0.0%	0.0%	0.0%	2.2%	0.0%	0.0%	0.0%	0.0%
11.25	0.8%	0.0%	0.0%	0.0%	0.0%	3.6%	0.0%	0.0%	0.0%	0.0%
12.75	1.5%	0.1%	0.0%	0.0%	0.0%	5.9%	0.1%	0.0%	0.0%	0.0%
14.25	2.4%	0.5%	0.0%	0.0%	0.0%	8.5%	0.5%	0.1%	0.0%	0.0%
15.75	3.6%	1.7%	0.3%	0.0%	0.0%	10.5%	2.4%	0.2%	0.0%	0.0%
17.25	5.0%	3.8%	1.6%	0.5%	0.0%	12.5%	5.7%	1.6%	0.1%	0.0%
18.75	6.5%	6.6%	4.2%	2.4%	0.4%	13.6%	11.7%	4.3%	1.6%	0.0%
20.25	8.8%	9.2%	8.3%	6.6%	2.6%	11.9%	16.8%	10.4%	5.3%	0.4%
21.75	10.7%	11.4%	12.1%	11.4%	7.9%	9.9%	19.8%	18.2%	13.5%	2.6%
23.25	60.0%	66.7%	73.5%	79.2%	89.2%	20.2%	42.9%	65.2%	79.5%	97.0%

*equivalent to half of the crash impact speed
Source: SIM simulation output

Table XIII-5 Passenger Vehicle Fleet Communication Rates by Technology Implementation Scenarios

Year of Implementation	Calendar Year	Scenario 1	Scenario 2	Scenario 3
1	2020	0.06%	0.03%	0.00%
2	2021	0.51%	0.26%	0.02%
3	2022	2.46%	0.95%	0.09%
4	2023	5.69%	2.20%	0.22%
5	2024	11.01%	4.08%	0.39%
6	2025	17.45%	6.66%	0.61%
7	2026	24.60%	10.02%	0.86%
8	2027	29.92%	14.19%	1.15%
9	2028	35.45%	18.88%	1.46%
10	2029	41.09%	23.99%	1.81%
11	2030	46.77%	29.46%	2.17%
12	2031	52.36%	35.17%	2.53%
13	2032	57.80%	41.02%	2.91%
14	2033	62.97%	46.90%	3.28%
15	2034	67.86%	52.75%	3.64%
16	2035	72.38%	58.44%	3.98%
17	2036	76.51%	63.87%	4.30%
18	2037	80.19%	68.92%	4.60%
19	2038	83.42%	73.51%	4.86%
20	2039	86.16%	77.59%	5.09%
21	2040	88.47%	81.13%	5.28%
22	2041	90.42%	84.16%	5.45%
23	2042	92.01%	86.70%	5.57%
24	2043	93.34%	88.83%	5.68%
25	2044	94.47%	90.62%	5.77%
26	2045	95.37%	92.10%	5.85%
27	2046	96.14%	93.35%	5.91%
28	2047	96.85%	94.45%	5.97%
29	2048	97.48%	95.43%	6.02%
30	2049	98.06%	96.29%	6.06%
31	2050	98.51%	97.02%	6.10%
32	2051	98.90%	97.63%	6.14%
33	2052	99.19%	98.16%	6.17%
34	2053	99.42%	98.62%	6.19%
35	2054	99.63%	99.00%	6.21%
36	2055	99.78%	99.32%	6.23%
37	2056	99.91%	99.57%	6.24%
38	2057	99.97%	99.73%	6.25%
39	2058	100.00%	99.84%	6.25%
40	2059	100.00%	99.91%	6.25%

Table XIII-6 Passenger Vehicle Fleet Communication Rate by Vehicle Types* and Technology Implementation Scenarios

Year of Implementation	Calendar Year	Scenario 1		Scenario 2		Scenario 3	
		PCs	LTVs	PCs	LTVs	PCs	LTVs
1	2020	0.03%	0.03%	0.02%	0.01%	0.00%	0.00%
2	2021	0.28%	0.23%	0.14%	0.12%	0.01%	0.01%
3	2022	1.34%	1.12%	0.52%	0.43%	0.05%	0.04%
4	2023	3.10%	2.58%	1.20%	1.00%	0.12%	0.10%
5	2024	6.01%	5.00%	2.23%	1.85%	0.21%	0.18%
6	2025	9.54%	7.91%	3.64%	3.02%	0.33%	0.28%
7	2026	13.47%	11.12%	5.48%	4.54%	0.47%	0.39%
8	2027	16.41%	13.51%	7.76%	6.43%	0.63%	0.52%
9	2028	19.47%	15.99%	10.33%	8.55%	0.80%	0.66%
10	2029	22.59%	18.50%	13.14%	10.85%	0.99%	0.82%
11	2030	25.74%	21.02%	16.15%	13.31%	1.19%	0.98%
12	2031	28.85%	23.51%	19.30%	15.87%	1.39%	1.14%
13	2032	31.87%	25.93%	22.54%	18.48%	1.60%	1.31%
14	2033	34.74%	28.23%	25.81%	21.09%	1.81%	1.47%
15	2034	37.44%	30.41%	29.07%	23.68%	2.01%	1.63%
16	2035	39.94%	32.44%	32.25%	26.19%	2.20%	1.78%
17	2036	42.20%	34.31%	35.28%	28.59%	2.38%	1.92%
18	2037	44.19%	36.01%	38.10%	30.82%	2.55%	2.05%
19	2038	45.90%	37.52%	40.64%	32.87%	2.69%	2.17%
20	2039	47.32%	38.84%	42.88%	34.71%	2.81%	2.28%
21	2040	48.48%	39.99%	44.80%	36.33%	2.91%	2.37%
22	2041	49.43%	40.99%	46.41%	37.75%	3.00%	2.45%
23	2042	50.09%	41.93%	47.64%	39.06%	3.05%	2.52%
24	2043	50.59%	42.75%	48.62%	40.21%	3.10%	2.58%
25	2044	50.99%	43.48%	49.39%	41.23%	3.13%	2.64%
26	2045	51.26%	44.11%	49.99%	42.11%	3.16%	2.69%
27	2046	51.46%	44.68%	50.45%	42.90%	3.18%	2.73%
28	2047	51.63%	45.22%	50.83%	43.62%	3.20%	2.77%
29	2048	51.77%	45.71%	51.14%	44.29%	3.21%	2.81%
30	2049	51.89%	46.17%	51.39%	44.90%	3.22%	2.84%
31	2050	51.95%	46.57%	51.57%	45.45%	3.23%	2.87%
32	2051	51.98%	46.92%	51.69%	45.94%	3.24%	2.90%
33	2052	51.97%	47.21%	51.77%	46.39%	3.24%	2.93%
34	2053	51.95%	47.47%	51.82%	46.80%	3.24%	2.95%
35	2054	51.93%	47.70%	51.85%	47.15%	3.24%	2.97%
36	2055	51.89%	47.89%	51.86%	47.46%	3.24%	2.99%
37	2056	51.85%	48.05%	51.84%	47.73%	3.24%	3.00%
38	2057	50.40%	49.57%	51.80%	47.93%	3.24%	3.01%
39	2058	50.36%	49.64%	51.75%	48.09%	3.23%	3.02%
40	2059	50.33%	49.67%	51.70%	48.21%	3.23%	3.02%

*The communication rates are used to discern the portion of benefit that would attributed to a specific vehicle type – a process for deriving the benefit for a specific model year of vehicles in order to measure cost-effectiveness.

Table XIII-7 Preliminary Annual Benefits* Estimates of IMA and LTA

Scenario 1

	Calendar	Crash Prevented		Fatalities Eliminated		MAIS 1-5 Injuries		PDOV	
Year	Year	Low	High	Low	High	Low	High	Low	High
1	2020	248	355	0.47	0.65	115	162	307	437
2	2021	2,104	3,020	3.96	5.52	975	1,377	2,607	3,714
3	2022	10,148	14,569	19.11	26.64	4,704	6,642	12,574	17,913
4	2023	23,472	33,698	44.21	61.62	10,879	15,364	29,083	41,433
5	2024	45,418	65,205	85.55	119.24	21,051	29,728	56,274	80,172
6	2025	71,983	103,344	135.59	188.98	33,365	47,117	89,190	127,066
7	2026	101,478	145,689	191.14	266.42	47,036	66,423	125,735	179,131
8	2027	123,424	177,195	232.48	324.03	57,208	80,787	152,927	217,869
9	2028	146,236	209,946	275.45	383.92	67,781	95,719	181,191	258,137
10	2029	169,501	243,347	319.27	445.00	78,565	110,948	210,018	299,206
11	2030	192,932	276,986	363.40	506.52	89,425	126,284	239,050	340,567
12	2031	215,991	310,092	406.84	567.06	100,113	141,378	267,621	381,271
13	2032	238,432	342,309	449.11	625.97	110,515	156,066	295,426	420,884
14	2033	259,759	372,927	489.28	681.97	120,400	170,026	321,851	458,531
15	2034	279,931	401,887	527.27	734.92	129,750	183,229	346,845	494,138
16	2035	298,576	428,656	562.39	783.88	138,392	195,434	369,947	527,052
17	2036	315,613	453,115	594.48	828.60	146,289	206,585	391,056	557,125
18	2037	330,793	474,909	623.08	868.46	153,325	216,522	409,866	583,922
19	2038	344,118	494,038	648.17	903.44	159,501	225,243	426,375	607,442
20	2039	355,420	510,265	669.46	933.11	164,740	232,641	440,379	627,394
21	2040	364,949	523,946	687.41	958.13	169,156	238,879	452,186	644,215
22	2041	372,993	535,494	702.56	979.25	172,885	244,144	462,153	658,414
23	2042	379,552	544,911	714.92	996.47	175,925	248,437	470,280	669,992
24	2043	385,039	552,787	725.25	1010.87	178,468	252,028	477,078	679,677
25	2044	389,700	559,480	734.03	1023.11	180,629	255,079	482,853	687,905
26	2045	393,413	564,810	741.02	1032.86	182,349	257,509	487,453	694,459
27	2046	396,589	569,370	747.01	1041.20	183,822	259,589	491,389	700,066
28	2047	399,518	573,575	752.52	1048.89	185,179	261,506	495,018	705,236
29	2048	402,117	577,306	757.42	1055.71	186,384	263,207	498,238	709,823
30	2049	404,509	580,741	761.93	1061.99	187,493	264,773	501,202	714,046
31	2050	406,366	583,406	765.42	1066.86	188,353	265,988	503,502	717,323
32	2051	407,974	585,715	768.45	1071.09	189,099	267,041	505,496	720,163
33	2052	409,171	587,433	770.71	1074.23	189,653	267,824	506,978	722,275
34	2053	410,119	588,795	772.49	1076.72	190,093	268,445	508,154	723,950
35	2054	410,986	590,039	774.13	1078.99	190,495	269,012	509,227	725,479
36	2055	411,604	590,927	775.29	1080.62	190,781	269,417	509,994	726,571
37	2056	412,141	591,697	776.30	1082.03	191,030	269,768	510,658	727,518
38	2057	412,388	592,052	776.77	1082.68	191,145	269,930	510,965	727,955
39	2058	412,512	592,230	777.00	1083.00	191,202	270,011	511,118	728,173

*Benefits are defined as potential lives saved, injuries prevented and the reduction in number of property-damaged vehicles

Table XIII-8 Preliminary Annual Benefits* Estimates of IMA and LTA

Scenario 2

	Calendar	Crash Prevented		Fatalities Eliminated		MAIS 1-5 Injuries		PDOV	
Year	Year	Low	High	Low	High	Low	High	Low	High
1	2020	124	178	0.23	0.32	57	81	153	218
2	2021	1,073	1,540	2.02	2.82	497	702	1,329	1,893
3	2022	3,919	5,626	7.38	10.29	1,816	2,565	4,856	6,918
4	2023	9,075	13,029	17.09	23.83	4,206	5,940	11,245	16,020
5	2024	16,830	24,163	31.70	44.19	7,801	11,016	20,854	29,709
6	2025	27,473	39,443	51.75	72.13	12,734	17,983	34,040	48,496
7	2026	41,334	59,341	77.86	108.52	19,158	27,055	51,214	72,963
8	2027	58,535	84,037	110.26	153.68	27,132	38,315	72,528	103,328
9	2028	77,882	111,813	146.70	204.47	36,099	50,978	96,499	137,479
10	2029	98,962	142,076	186.40	259.81	45,869	64,776	122,617	174,689
11	2030	121,526	174,471	228.90	319.05	56,328	79,545	150,575	214,520
12	2031	145,080	208,287	273.27	380.89	67,246	94,963	179,760	256,098
13	2032	169,212	242,933	318.73	444.25	78,431	110,759	209,661	298,697
14	2033	193,468	277,756	364.41	507.93	89,674	126,635	239,714	341,513
15	2034	217,600	312,401	409.87	571.28	100,859	142,431	269,615	384,111
16	2035	241,072	346,099	454.08	632.91	111,738	157,794	298,697	425,544
17	2036	263,471	378,257	496.27	691.71	122,121	172,456	326,451	465,084
18	2037	284,303	408,165	535.51	746.40	131,776	186,092	352,263	501,857
19	2038	303,238	435,348	571.17	796.11	140,553	198,485	375,723	535,280
20	2039	320,068	459,511	602.87	840.30	148,354	209,502	396,576	564,989
21	2040	334,671	480,476	630.38	878.64	155,122	219,060	414,670	590,767
22	2041	347,170	498,421	653.92	911.45	160,916	227,241	430,157	612,830
23	2042	357,648	513,463	673.66	938.96	165,772	234,100	443,139	631,326
24	2043	366,434	526,078	690.21	962.03	169,845	239,851	454,026	646,836
25	2044	373,818	536,679	704.12	981.41	173,267	244,684	463,175	659,870
26	2045	379,924	545,444	715.62	997.44	176,097	248,680	470,740	670,647
27	2046	385,080	552,847	725.33	1010.98	178,487	252,055	477,129	679,750
28	2047	389,618	559,361	733.88	1022.89	180,590	255,025	482,751	687,759
29	2048	393,660	565,165	741.49	1033.51	182,464	257,672	487,760	694,895
30	2049	397,208	570,258	748.17	1042.82	184,108	259,994	492,156	701,158
31	2050	400,219	574,582	753.85	1050.73	185,504	261,965	495,887	706,473
32	2051	402,735	578,194	758.59	1057.33	186,671	263,612	499,005	710,915
33	2052	404,922	581,333	762.70	1063.07	187,684	265,043	501,713	714,775
34	2053	406,819	584,057	766.28	1068.05	188,563	266,285	504,065	718,124
35	2054	408,387	586,308	769.23	1072.17	189,290	267,311	506,007	720,891
36	2055	409,707	588,203	771.72	1075.64	189,902	268,175	507,642	723,221
37	2056	410,738	589,683	773.66	1078.34	190,380	268,850	508,920	725,042
38	2057	411,398	590,631	774.90	1080.08	190,686	269,282	509,738	726,207
39	2058	411,852	591,282	775.76	1081.27	190,896	269,579	510,300	727,008

*Benefits are defined as potential lives saved, injuries prevented and the reduction in number of property-damaged vehicles

Table XIII-9 Preliminary Annual Benefits* Estimates of IMA and LTA

Scenario 3

	Calendar	Crash Prevented		Fatalities Eliminated		MAIS 1-5 Injuries		PDOV	
Year	Year	Low	High	Low	High	Low	High	Low	High
1	2020	0	0	0.00	0.00	0	0	0	0
2	2021	83	118	0.16	0.22	38	54	102	146
3	2022	371	533	0.70	0.97	172	243	460	655
4	2023	908	1,303	1.71	2.38	421	594	1,124	1,602
5	2024	1,609	2,310	3.03	4.22	746	1,053	1,993	2,840
6	2025	2,516	3,613	4.74	6.61	1,166	1,647	3,118	4,442
7	2026	3,548	5,093	6.68	9.31	1,644	2,322	4,396	6,262
8	2027	4,744	6,811	8.94	12.45	2,199	3,105	5,878	8,374
9	2028	6,023	8,647	11.34	15.81	2,792	3,942	7,462	10,631
10	2029	7,466	10,719	14.06	19.60	3,461	4,887	9,251	13,180
11	2030	8,952	12,851	16.86	23.50	4,149	5,859	11,091	15,801
12	2031	10,437	14,983	19.66	27.40	4,837	6,831	12,931	18,423
13	2032	12,004	17,234	22.61	31.52	5,564	7,857	14,874	21,190
14	2033	13,530	19,425	25.49	35.52	6,271	8,856	16,765	23,884
15	2034	15,015	21,557	28.28	39.42	6,960	9,828	18,605	26,506
16	2035	16,418	23,571	30.92	43.10	7,610	10,746	20,343	28,981
17	2036	17,738	25,466	33.41	46.57	8,222	11,610	21,978	31,311
18	2037	18,976	27,243	35.74	49.82	8,795	12,421	23,511	33,496
19	2038	20,048	28,782	37.76	52.63	9,292	13,123	24,840	35,389
20	2039	20,997	30,145	39.55	55.12	9,732	13,744	26,016	37,064
21	2040	21,781	31,270	41.03	57.18	10,095	14,257	26,987	38,448
22	2041	22,482	32,277	42.35	59.02	10,421	14,716	27,856	39,685
23	2042	22,977	32,987	43.28	60.32	10,650	15,040	28,469	40,559
24	2043	23,431	33,639	44.13	61.51	10,860	15,337	29,032	41,360
25	2044	23,802	34,172	44.83	62.49	11,032	15,580	29,492	42,016
26	2045	24,132	34,645	45.45	63.36	11,185	15,796	29,900	42,598
27	2046	24,379	35,001	45.92	64.01	11,300	15,958	30,207	43,035
28	2047	24,627	35,356	46.39	64.66	11,415	16,120	30,514	43,472
29	2048	24,833	35,652	46.78	65.20	11,510	16,255	30,769	43,836
30	2049	24,998	35,889	47.09	65.63	11,587	16,363	30,974	44,127
31	2050	25,163	36,126	47.40	66.06	11,663	16,471	31,178	44,419
32	2051	25,328	36,363	47.71	66.50	11,740	16,579	31,383	44,710
33	2052	25,452	36,541	47.94	66.82	11,797	16,660	31,536	44,928
34	2053	25,534	36,659	48.10	67.04	11,835	16,714	31,638	45,074
35	2054	25,617	36,777	48.25	67.25	11,874	16,768	31,740	45,220
36	2055	25,700	36,896	48.41	67.47	11,912	16,822	31,843	45,365
37	2056	25,741	36,955	48.48	67.58	11,931	16,849	31,894	45,438
38	2057	25,782	37,014	48.56	67.69	11,950	16,876	31,945	45,511
39	2058	25,782	37,014	48.56	67.69	11,950	16,876	31,945	45,511

*Benefits are defined as potential lives saved, injuries prevented and the reduction in number of property-damaged vehicles

XIV. Appendix B: List of Policy, Standards and Research Needs

A. Policy needs

B. Standards needs

C. Research needs

XV. Appendix C: List of Tables, Figures and Equations

A. Tables

B. Figures

C. Equations

Appendix XI. USDOT, *Research Data Exchange Release 2.3: Safety Pilot Model Deployment Data.*

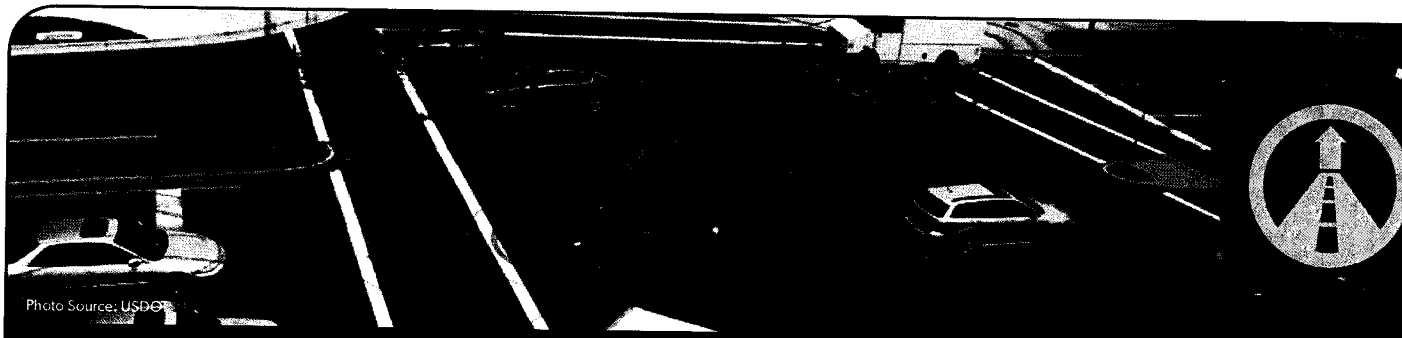

Photo Source: USDOT

MOBILITY

RESEARCH DATA EXCHANGE RELEASE 2.3

SAFETY PILOT MODEL DEPLOYMENT DATA

The Safety Pilot Model Deployment (SPMD) program was sponsored by the U.S. Department of Transportation (USDOT) National Highway Traffic Safety Administration, Intelligent Transportation Systems Joint Program Office, Federal Highway Administration, Federal Motor Carrier Safety Administration, and Federal Transit Administration. The SPMD program was a research initiative featuring real-world implementation of connected vehicle safety technologies, applications, and systems in everyday vehicles and multimodal driving conditions. The objectives of the SPMD program were to:

- Demonstrate connected vehicle technologies in a real-world, multimodal environment
- Determine driver acceptance and adoption of vehicle-based safety systems
- Evaluate the feasibility, scalability, security, and interoperability of dedicated short-range communications (DSRC) technology
- Assess options to accelerate safety benefits.

Two months of SPMD data are now available for consumption and use via the Research Data Exchange (RDE) (www.its-rde.net). The RDE serves as the USDOT's central repository for connected vehicle data for researchers and application developers. It provides users with the ability to download connected vehicle data and appropriate documentation, create research projects, collaborate with other users, and comment on hosted data sets.

SPMD Program Overview

The SPMD program was a comprehensive data collection effort under real-world conditions, with multimodal traffic and vehicles equipped with vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication devices. These vehicles used DSRC to communicate Basic Safety Messages (BSMs) containing vehicle operation information, such as speed, location, and direction, at a frequency of 10 messages per second.

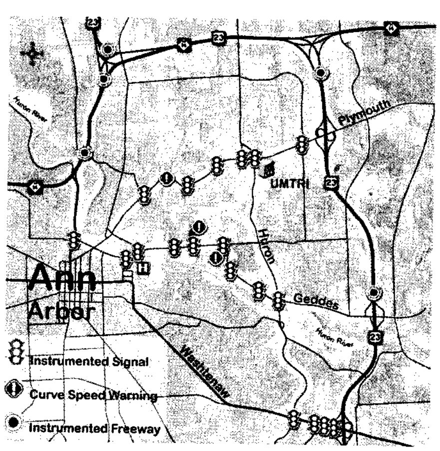

Figure 1. Safety Pilot Model Deployment Site Plan, Ann Arbor, MI

The SPMD was held in Ann Arbor, Michigan (see Figure 1), starting in August 2012. The deployment covered over 73 lane-miles and included approximately 3,000 onboard vehicle equipment and 30 roadside equipment (RSE). A majority of the RSEs were placed at signalized intersections, while others were strategically installed

Safety Pilot Data Available on the RDE

The RDE houses two months of data from the SPMD program. The SPMD data sets contain sanitized mobility data elements collected from about 3,000 vehicles, equipped with connected vehicle technologies, traversing Ann Arbor, Michigan. These hyper-frequent, hyper-local naturalistic driving data will be a valuable resource for researchers and application developers to support the development of the next generation of transportation solutions.

The six SPMD data sets located on the RDE include:

- The DAS1 data set contains four text-based data files from vehicles equipped by the University of Michigan Transportation Research Institute (UMTRI), providing vehicle kinematic and geospatial information and trip summaries.
- The DAS2 data set contains three text-based vehicle operation data files from vehicles equipped by the Crash Avoidance Metrics Partnership (CAMP), providing similar data to the DAS1 data set.
- The BSM data set contains 15 files, each containing vehicle attributes (e.g., location, speed, and heading), in addition to a file with other attributes (e.g., brake application, status of wipers).
- The RSE data set contains 13 files of messages transmitted or received by RSEs, including BSMs, signal phase and timing (SPaT) messages, and traveler information messages (TIMs).
- The weather data set consists of corresponding weather information from the National Oceanic and Atmospheric Administration's National Climatic Data Center.
- The network data set consists of two CSV files that contain traffic count data from Ann Arbor.

U.S. Department of Transportation

to support other applications such as curve speed warnings. The vehicles were equipped with one of the following four types of devices to enable V2V and V2I communications:

1. Integrated safety devices (67 vehicles)
2. Aftermarket safety devices (300 vehicles)
3. Retrofit safety devices (19 vehicles)
4. Vehicle awareness devices (2,450 vehicles).

Many vehicles were equipped with additional data acquisition systems (DAS) with internal logging capability, and some DAS logged video data (both internal and external to the vehicle) and audio recordings (primarily of safety alerts and warnings).

SPMD Data Available in the RDE

The SPMD data available are the text-based (non-video, non-audio) data. These data are accompanied by a downloadable data dictionary and metadata document that provides information to support its use. The RDE SPMD data environment includes six data sets:

- Two driving data sets, consisting of data acquired using two types of DAS—DAS1 and DAS2
- One BSM data set, consisting of data generated by equipped vehicles
- One RSE data set, consisting of BSMs received by RSEs and signal timing and curve speed warning messages transmitted by RSEs
- One weather data set, consisting of weather information for the time periods corresponding to data collection.
- One network data set containing traffic count data from Ann Arbor.

Each data set includes multiple data files. For instance, the BSM data set includes 15 files with information such as vehicle position and speed, brake system data, and summaries for each completed trip.

To protect the SPMD participants' identities, all the data elements that included personally identifiable information were removed. Data elements that could be paired with other publicly available data were also deleted. Additionally, since vehicle trajectories could potentially reveal the identity of participants, a sanitization algorithm was developed to truncate these trajectories to mask trip origins and destinations.

Value of the SPMD Data Collection

The collected data has significant research value by providing connected vehicle information that is hyper-frequent and hyper-local. It contains contextual mobility and environmental data to further describe the conditions under which these data were collected, including traffic flow information, traffic signal operation, and weather. Some examples of research topics that could use this data include:

- Uncovering safety hot spots in Ann Arbor
- Developing algorithms to estimate travel time throughout the Ann Arbor region
- Evaluating vehicle performance with lane-level precision.

These data will support continued advancements in the connected vehicle domain, as well as the development of applications to improve transportation operation and maintenance.

Data Graph Tool for SPMD Data

RDE Release 2.3 now includes the Data Graph tool as an alternative method to view the data and select subsets of the SPMD data environment. Graph nodes present the number of records and the volume of data by hour for each day. Registered users are able to add data subset files corresponding to selected graph nodes to their download cart. A new download process eliminates waiting for a custom download; a link is emailed to the user when the data file has been produced and is ready to send.

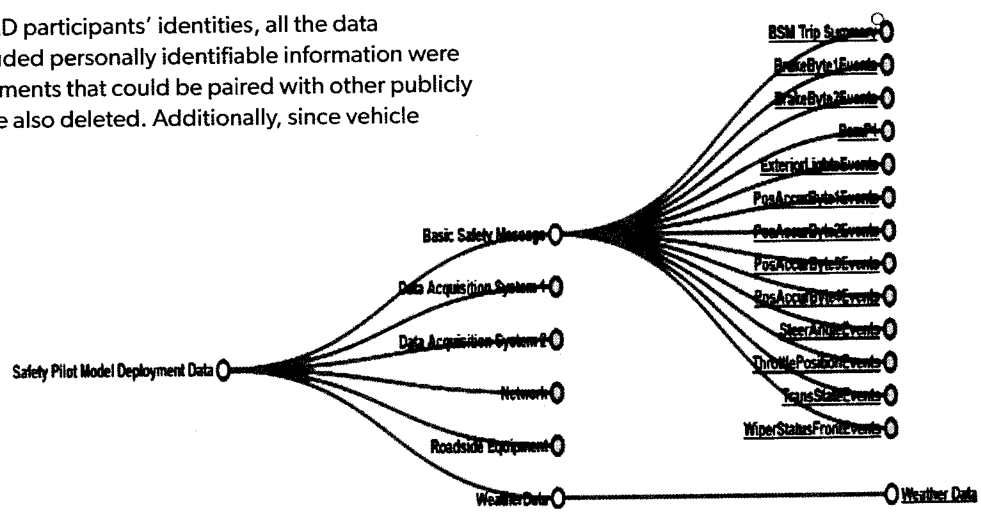

Figure 2. Data Graph Tool for SPMD Data

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FHWA-JPO-16-286

Appendix XII. Press Release, Savari, Inc., *Savari Launches Next-Gen V2X Solutions to Accelerate Adoption of Safety Apps in Connected and Self-driving Cars* (June 13, 2016).

SAVARI™

Savari Launches Next-Gen V2X Solutions to Accelerate Adoption of Safety Apps in Connected and Self-driving Cars

Higher Performance, Hardware Security, Automotive-Grade OBUs and Higher Performance, Compact and Ruggedized RSUs

ITS AMERICA, SANTA CLARA, Calif. June 13, 2016, Savari, Inc. announced its next generation of MobiWAVE™ On-Board Units (OBUs), StreetWAVE™ Road-Side Units (RSUs) and V2X middleware. These new solutions add to Savari's industry-leading experience in V2X communication technology and target automotive manufacturers, tier one suppliers and governments that want to make our roadways safer and more efficient.

V2X communication technology is widely recognized throughout the industry as a ready-to-deploy option to bring advanced situational awareness to the driver through V2V (vehicle-to-vehicle), V2I (vehicle-to-infrastructure) and V2P (vehicle-to-pedestrian) safety applications. V2X systems can operate independently or complement other connected vehicle technologies, and they offer the benefit of working in a non-line-of-sight environment with a 0.6 mi./1 km range. Savari's life-saving V2X solutions are roadway proven, amassing over 15 million miles and four hundred thousand hours of public safety pilot testing with the USDOT.

Savari MobiWAVE OBUs

The new MobiWAVE OBU family of products for vehicles are completely redesigned, featuring an automotive grade processor that delivers 4x increase in computing power over the previous platform and multiple wireless radio support, including DSRC, Wi-Fi, Bluetooth and cellular radios. The MobiWAVE platform is an industry standard and software configurable as a Vehicle Awareness Device (VAD), Aftermarket Safety Device (ASD) and a complete-off-the-shelf device for automotive manufacturers, tier one suppliers and aftermarket suppliers. The platforms feature automotive controller area network (automotive CAN), multiple forms of storage, a display, multi-axis sensor and a built-in speaker and microphone in a compact design. The platform also provides many industry firsts for a V2X system like position accuracy improvements especially in urban canyon, fast boot up, high reliability design, optional hardware crypto accelerator for line rate verification of received messages, optional built-in rechargeable battery with smart cutoff and much more.

Savari StreetWAVE RSU

Savari is releasing a lower cost version of its current StreetWAVE RSU in August and its next generation StreetWAVE RSU in the fourth quarter of 2016 that offers several enhancements for smart city and roadway infrastructure deployments. The next-generation model supports the latest USDOT DSRC specification, is fully version USDOT RSU 4.0-compliant, offers easy remote management via any SNMP browser and is available in a ruggedized compact form factor. The RSU features built-in Wi-Fi/BT and Cellular, optional crypto-acceleration for line rate security verification and a slew of other features that increase performance and reliability. Savari has created a high performance and cost-effective RSU that's ideal for citywide or smaller scale type of deployments. Savari StreetWAVE RSUs are deployed in major public U.S. smart city testbeds, with over 90 percent of currently installed road-side-units, covering 130 square miles of public area.

Savari V2X Middleware

The Savari MobiWAVE SDK provides feature-rich libraries for developing V2V and V2I applications for a wide range of customers from automotive manufacturers to municipal transportation departments. The company's V2X software stack is comprised of over 1.5 million lines of code. The latest release is compliant to the 2016 version of the USDOT specifications. Savari MobiWAVE SDK has been used to develop advanced ITS applications such as predictive safety & mobility applications: forward collision warning, electronic emergency brake light, curve speed warning, work zone warning, pedestrian detection, transit signal priority for emergency responders and more. Customers can now use the Savari V2X software, which is in use in various major testbed deployments in the United States and Europe, including UMTRI Safety Pilot, Crash Avoidance Metrics Partnership (CAMP), Virginia Connected Test Bed, Caltrans/UC Berkeley PATH Test Bed and Car-2-Car Communication Consortium.

For more information about Savari's V2X portfolio, please visit http://www.savari.net/technology/ or visit the Savari booth (#916) at ITS America, June 12-16, at the McEnery Convention Center in San Jose, Calif. ITS America attendees can also sign-up at the booth for an in-car technology demonstration of Savari's V2V safety applications that include Forward Collision Warning, Blind Spot Warning, Lane Change Assist and Intersection Movement Assist.

Comments on the News:

"At Savari, we are passionate about making the world's roadways safer for everyone. Our V2X communication solutions have demonstrated in public testing that they can prevent accidents and save lives. Our next-generation on-board units, road-side units and intelligent transportation applications leverage the latest, advanced technologies combined with V2X expertise that spans eight years of collaboration with the USDOT and several transportation departments, automakers and tier one suppliers from around the world. As cities increasingly look to deploy smart infrastructure and manufacturers add V2X technology to their vehicles, there's no ceiling to how many people will be touched by our technology," said Ravi Puvvala, CEO, Savari.

About Savari, Inc.

Savari seeks to make the world's roadways smarter and safer by deploying advanced wireless sensor technologies and software for V2X environments to support a growing portfolio of intelligent transportation services. With more than 150 man-years of V2X learning and development and 15 million-plus miles per year of public testing, Savari is a leader in V2X technology. Savari is headquartered in Santa Clara, Calif., and has offices in Detroit, Mich., Munich, Germany, Seoul, Korea and Bangalore, India. The company is comprised of a core team of industry veterans from the automotive, semiconductor, software and telecommunications industries. Savari is partnering with automotive OEMs, system integrators, chipset vendors and industry groups like the U.S. Department of Transportation. For more information, visit savari.net.

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Appendix XIII. NHTSA, *Vehicle-to-Vehicle Communications.*

5-Star Safety Ratings
Air Bags
Child Safety at Parents Central
Resources
Rollover
Safety Technology
AEB
Keyless
Tires
Tires Rating
Passenger Van Safety

Vehicle-to-Vehicle Communications

Vehicle-to-vehicle (V2V) technology allows equipped vehicles to wirelessly exchange information about surrounding vehicles' speed and positions to help drivers better avoid crashes. V2V employs dedicated short-range communications (DSRC), a variation of Wi-Fi tailored for moving vehicles. This technology allows vehicles to rapidly broadcast and receive messages (up to 10 times per second) so there is a 360-degree "awareness" of other vehicles in the proximity. Communication messages have a range of approximately 300 meters and can detect dangers obscured by traffic, terrain, or weather. Prototype V2V systems have used visual, tactile, and audible alerts—or a combination of these—to warn drivers of the potential for a crash.

The current proposed design for the V2V system employs strong security and is compliant with the latest standards from the National Institute of Standards and Technology, which develops guidelines, best practices, and standards for information technology systems. V2V technology does not exchange or record a consumer's personal information, nor does it track a vehicle's movements, which helps protect a driver's privacy.

NHTSA has worked with the automotive industry and academic institutions for more than a decade to advance V2V's lifesaving potential into reality. NHTSA estimates that when fully deployed, V2V technology has the potential to address approximately 80 percent of multi-vehicle crashes. NHTSA plans to publish a rulemaking proposal on this important technology in 2016.

Because of the cooperative nature of the technology, the benefits are only realized when surrounding vehicles also are equipped with V2V communications, and maximum benefits are achieved when all vehicles can communicate with each other. To this end, the government has a pivotal role in standardizing the communications protocols to ensure interoperability now—and into the future—and to ensure that all vehicles, over time, participate in safety communications.

More Information

Automated Vehicle Technologies

Vehicle Cybersecurity

Appendix XIV. NHTSA, *Overview of NHTSA Priority Plan for Vehicle Safety and Fuel Economy, 2015 to 2017.*

Overview of NHTSA Priority Plan for Vehicle Safety and Fuel Economy, 2015 to 2017

The primary mission of the National Highway Traffic Safety Administration (NHTSA) is to "save lives, prevent injuries, and reduce economic costs due to road traffic crashes." NHTSA strives to meet its mission through a wide range of behavioral and vehicle safety programs. NHTSA's mission also includes a commitment to environmental sustainability through setting and enforcing fuel economy and efficiency standards.

NHTSA's vehicle safety program seeks to meet these objectives through:

- development, issuance and enforcement of Federal motor vehicle safety standards (FMVSS), regulations and fuel economy/efficiency standards,
- development and dissemination of vehicle and equipment performance information to consumers, including through its New Car Assessment Program (NCAP),
- investigation of possible safety defects and noncompliance, and when appropriate, seeking recalls of vehicles and equipment that pose an unreasonable safety risk or do not comply with the FMVSS,
- research to define safety problems and to support the development of standards to address these problems,
- research to aid the development and deployment of advanced technologies that improve safety and fuel efficiency, and
- collection and analysis of crash data to identify potential safety problems and to assess the effectiveness of proposed solutions.

This plan serves as an internal management tool as well as a means to communicate to the public and regulators in other countries NHTSA's highest priorities. Our hope is that this plan will advance motor vehicle safety by providing information that our stakeholders and others can use for their own planning as well as encouraging regulatory cooperation as we work to improve safety for the American public.

The plan describes only programs and projects that are priorities and does not include the many other important projects as well as routine activities for which the Office of Vehicle Safety or other NHTSA offices are responsible. Of course, as with any plan, as circumstances change the agency may need to adjust these priorities.

The selection of projects as priorities is informed by a wide variety of external and internal factors. The primary driving forces are **crash data** indicating the areas in greatest need of improvement and knowledge of the technologies that are or can be expected to become available to address those areas. The data tell us which crash scenarios account for the largest number of crashes as well as the largest number of moderate, serious and fatal injuries.

Motor vehicle crashes killed 32,719 people and injured over 2.3 million others in 2013. In addition to the terrible personal toll, these crashes have a huge economic impact on our society with an estimated annual cost of $242 billion, which is an average of $784 for every person in the United States. These crashes also result in $594 billion in societal harm from loss of life and the pain and decreased quality of life due to injuries.

The detailed data also indicate that significant current behavioral issues such as the failure to use seat belts, drunk driving and driver error need to be addressed in order to achieve progress in reducing injuries and fatalities. In 2013, 10,458 fatally injured occupants of passenger vehicles were not restrained, accounting for about 49 percent of all fatally injured passenger vehicle occupants. While seat belts saved 12,584 lives in 2013, it is estimated that 2,800 additional lives would have been saved if all unrestrained passenger vehicle occupants had worn their belts. Also, in 2013, 10,076 people were killed in drunk driving crashes. The majority of those people died in crashes involving drivers with a blood alcohol concentration (BAC) of .15 or higher – nearly double the legal limit. We also know that driver error is a significant contributor to crashes. NHTSA has found that driver error was the critical reason in 94 percent of crashes.

The crash data, combined with **testing, computer modeling and simulation with regard to new technologies,** also aid us in determining which current and future technological countermeasures offer the greatest promise in reducing injuries and preventing crashes. New safety technologies related to improved crashworthiness and crash avoidance have prevented a significant number of deaths over the years. Vehicle safety technologies saved an estimated 613,501 lives from 1960 through 2012. The annual number of lives saved grew quite steadily from 115 in 1960, when a small number of people used lap belts, to 27,621 in 2012, when most cars and light trucks were equipped with numerous modern safety technologies and belt use on the road reached 86 percent.

Of course, many other factors shape NHTSA's priorities. For example, the plan includes programs and projects that satisfy **Congressional mandates**. NHTSA also considers **recommendations offered by the National Transportation Safety Board (NTSB)**.

In addition to addressing current issues, our priorities also look toward the future. Motor vehicles and drivers' relationships with them are likely to change significantly in the next ten to twenty years, perhaps more than they have changed in the last 100 years. Recent and **continuing advances in automotive technology and current research on and testing of exciting vehicle innovations** have created completely new possibilities for improving vehicle safety, increasing environmental benefits, expanding mobility, and creating new economic opportunities for jobs and investment. They also present new challenges.

In 2012, the National Research Council (NRC) of the National Academies published "The Safety and Challenge of Automotive Electronics: Insights from Unintended Acceleration." In view of the fact that today's vehicles are heavily reliant on complex electronic control systems and reflect the broader industry shift toward electronics and software, the NRC made recommendations that led the agency to develop research roadmaps that guide its research into the reliability and security of safety-critical electronic control systems. The report's recommendations, as well as the contents of the research roadmaps, have informed the projects contained in this priority plan.

The agency also is sensitive to the fact that the issue of privacy is an important factor in considering future technologies. The agency has the ability to address privacy concerns in order to promote the public acceptance and use of those technologies.

In 2013, NHTSA released its "Preliminary Statement of Policy Concerning Automated Vehicles." The Statement describes some of the broader changes that are occurring in vehicle technologies: (1) in-vehicle crash avoidance systems that provide warnings and/or limited automated control of safety functions; (2) self-driving vehicles; and (3) vehicle-to-vehicle (V2V) communications that support various crash avoidance applications. The Statement also describes the various levels of vehicle automation ranging from no automation to full self-driving automation and outlines our research plans. NHTSA has been actively involved in researching these advanced technologies.

In 2014, in response to legislation known as "Moving Ahead for Progress in the 21st Century" or "MAP-21," NHTSA outlined recent findings with respect to vehicle electronics and the security of those electronics. In addition, we sought comment on our electronics and cybersecurity research program that is aimed at addressing the most critical safety needs of vehicles. Public responses to that notice have informed the projects in this plan.

NHTSA is working cooperatively with other DOT agencies on this research. Initially, the agency has identified three key areas where it has begun or plans to conduct research on the more advanced automated vehicle systems: human factors research, development of system performance requirements and addressing electronic control system safety. These research areas are reflected in the projects listed in this priority plan.